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:
combustion
exothermic reaction
propulsion
proportion
rocketry

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
- 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. To prepare yeast water, dissolve one tablespoon of dry yeast in 100 mL of water.
3. To make calibrated pipette bulbs:
    - cut the pipette near the graduation closest to the bulb trying to keep the cut straight
    - with a permanent marker or paint pen, divide one pipette into six equal sections
    - use this pipette as a guide to mark the remaining pipettes.
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.)

5. Decide on a launching area for the rockets and mark it appropriately.

To make your own Piezoelectric sparking units from gas grill igniters:

Materials:

- Gas grill replacement igniter, 1 per sparking unit (available at hardware stores)
- Electrical tape
- Film canister lid, 1 per sparking unit
- Hot glue gun and glue (or water-proof adhesive)
- 24-gauge speaker wire (solid, not stranded: Radio Shack #278-1509), 10 cm per sparking unit
- Wire strippers
- Scissors

Constructing the piezoelectric sparkers:

- Using scissors, split **one** end of a 10 cm length of speaker wire down the center 4-5 cm. Be careful to ensure that the insulation around each strand is not damaged.
- Strip the last 2 cm of insulation from both sides of the split portion and strip just the tip of the unsplit end.
- Cut two pieces of electrical tape long enough to wrap around the gas grill igniter.
- Place one of the stripped ends of the split speaker wire against the metal tab of the igniter and secure with electrical tape. A dot of glue from the glue gun could be used before taping to make the connection more secure, but this is optional.
- Bend the other stripped end of the wire back and push it into the tip of the igniter so that it makes contact with the electrode pole in the tip. Again, secure with electrical tape.
- Poke or melt a hole in the film canister cap and slide it over the wire so that it rests atop the ignitor.
- Test the sparker, holding it as a syringe with your thumb on the trigger button and fingers over the film canister cap. 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 or one of the wires has come loose. Check to make sure the wire in the tip of the igniter is still in place, and that the wire is still on the igniter’s metal tab.
- To avoid shocks, go around the entire ignitor body with a wrapping of electrical tape.
- Secure the film canister lid in place with a drop of glue from the glue gun on the top where the wire protrudes from it.
- Bend the last 1 cm of the tip of the speaker wire up at a 90 degree angle to create a launch pad for the pipette bulb to rest over.

Alternative method of making the piezoelectric sparkers from fireplace lighters:
Materials**:**

- piezoelectric butane charcoal/ fireplace lighter
- 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
- wire strippers

Constructing the piezoelectric sparker:

- 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 if the level of your students requires a bit more structure. In this case, you may pick a few proportions for them to try (recommended proportions are: 0,6; 2,4; 3,3; 4,2; 6,0), and a standard that they are to measure (i.e. volume of 'popping' sound).

1. Divide the students in lab groups of 3-5 students per group.
2. Pour the chemicals in the generators for each lab group.

3. Use 2-3 pieces of mossy zinc in the hydrogen generator (depending on their size). You will fill this generator with HCl to about 10 cm from the top. 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.
4. In the oxygen generator, fill with hydrogen peroxide to about 10 cm from the top. Add 10-20 drops of yeast water.
5. Make sure the students put the lids on the generators and place them in the petri dish of water.
6. Remind students about making and recording observations throughout the experiment.
7. Students could decide on their own test parameter (i.e. loudness of pop, brightness of flash) and its measurement (this will of course be subjective).
8. 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).
9. Note: If either generator reaction slows down so that it takes more than one minute to fill the bulb with gas, fresh solution should be put in the micro-generators.
10. After the groups have completed their experiments, lead a discussion with the class. Questions you may want to ask include:
    - What are the end products of this reaction? *(heat, light, water, sound, thrust)*
    - What proportion worked the best for the combustion reaction? *(2:4 or 1:2)* What molecule has these proportions of hydrogen and oxygen? *(water–H_2O)*
    - Why is the pipette propelled forward? *(the reaction causes pressure to be forced out of the end of the pipette, propelling it forward)*
    - What proportion of fuels do you think that NASA uses in the Space Shuttle *(1 part oxygen to 2 parts hydrogen)*

Answer Key--Science Journal

12. 2 parts oxygen to 4 parts hydrogen
13. Answers will vary
14. Answers will vary but should include the knowledge of the approximate nature of their measuring techniques. Solutions could 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 differences.
15. Oxygen and hydrogen molecules collide as they mix in the bulb but do not have the necessary energy to react. The electric spark supplies that energy.

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° is best, but with the air resistance in the classroom, something less than 45° 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.
4. Research how NASA uses combustible hydrogen fuel in its space program

Related Reading

- ***Hydrogen (Sparks of Life: Chemical Elements That Make Life Possible)*** by Jean Blashfield (Raintree, 1998)
  Presents the basic concepts of this central element of the universe.
- ***Hydrogen (The Elements, Set 2)*** by John Farndon (Benchmark Books, 1999)
  This book presents the basics of hydrogen--the element's atomic structure; where and how it occurs in nature; its reactions, isotopes, and compounds, as well as its uses, practical applications, and importance in our lives.

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
Nature of Matter	**Standard 1**	**SC.A.1.3-**				X	X		
	Standard 2	**SC.A.2.3-**		X					
Energy	**Standard 1**	**SC.B.1.3-**	X	X		X			
	Standard 2	**SC.B.2.3-**							
Force and Motion	**Standard 1**	**SC.C.1.3-**	X						
	Standard 2	**SC.C.2.3-**					X		
Nature of Science	**Standard 1**	**SC.H.1.3-**		X			X		X
	Standard 2	**SC.H.2.3-**							
	Standard 3	**SC.H.3.3-**	X			X			

Benchmark SC.A.1.3.4 - The student knows that atoms in solids are close together and do not move around easily; in liquids, atoms tend to move farther apart; in gas, atoms are quite far apart and move around freely.

Grade Level Expectations

The student:

Sixth

- understands that matter may exist as solids, liquids, and gases.

Benchmark SC.A.1.3.5 - The student knows the difference between a physical change in a substance and a chemical change.

Grade Level Expectations

The student:

Sixth

- knows the physical properties of various substances
- knows the chemical properties of various substances
- knows the difference between a physical and chemical change

Seventh

- knows that chemical changes result in new substances with different characteristics

Eighth

- knows how to use clues to determine whether a change is chemical or physical.

Benchmark SC.A.2.3.2 - The student knows the general properties of the aton and accepts that single atoms are not visible.
Grade Level Expectations
The student:
Eighth
- knows that when electrons are transferred from one substance to another, the general properties of both substances change.

Benchmark SC.B.1.3.1 - The student identifies forms of energy and explains that they can be measured and compared.
Grade Level Expectations
The student:
Sixth
- knows different types of energy and the units used to quantify the energy

Eighth
- knows examples of natural and man-made systems in which energy is transfered from one form to another.

Benchmark SC.B.1.3.2 - The student knows that energy cannot be created or destroyed, but only changed from one form to another.
Grade Level Expectations
The student:
Sixth
- understands that energy can be changed in form
- uses examples to demonstrate common energy transformations.

Benchmark SC.B.1.3.4 - The student knows that energy conversions are never 100% efficient.
Grade Level Expectations
The student:
Seventh
- knows that useful energy is lost as heat energy in every energy conversion

Eighth
- knows that energy conversions are never 100% efficient and that some energy is transformed to heat and is unavailable for further useful work
- knows that a transfer of thermal energy occurs in chemical reactions.

Benchmark SC.C.1.3.1 - The student knows that the motion of an object can be described by its position, direction of motion, and speed.
Grade Level Expectations
The student:
Sixth
- knows that a change in motion and position can be measured

- knows ways to estimate speed

Seventh

- knows that the motion of an object can be described by its position, direction of motion, and speed.

Benchmark SC.C.2.3.5 - The student understands that an object in motion will continue at a constant speed and in a straight line until acted upon by a force and that an object at rest will remain at rest until acted upon by a force.

Grade Level Expectations

The student:

Sixth

- knows that an object at rest will stay at rest unless acted upon by an outside force
- knows that an object in motion will remain in motion unless acted upon by an outside force

Eighth

- understands that an object in motion will continue at a constant speed and in a straight line until acted upon by a force and that an object at rest will remain at rest until acted upon by a force.

Benchmark SC.H.1.3.2 - The student knows that the study of the events that led scientists to discoveries can provide information about the inquiry process and its effects.

Grade Level Expectations

The student:

Sixth

- uses systematic, scientific processes to develop and test hypotheses

Seventh

- uses systematic, scientific processes to solve problems and reach conclusions

Eighth

- extends and refines use of systematic, scientific processes to develop and test hypotheses.

Benchmark SC.H.1.3.5 - The student knows that a change in one or more variables may alter the outcome of an investigation.

Grade Level Expectations

The student:

Sixth

- uses appropriate experimental design, with consideration for rules, time, and materials required to solve a problem

Seventh

- extends and refines use of appropriate experimental design, with consideration for rules, time, and materials required to solve a problem

Eighth

- extends and refines use of rules, time, and materials in ways that ensure the identification and separation of variable in an experiment to solve a problem.

Benchmark SC.H.1.3.7 - The student knows that when similar investigations give different results, the scientific challenge is to verify whether the differences are significant by further study.

Grade Level Expectations

The student:

Sixth

- uses criteria necessary to determine the veracity of the data

Seventh

- uses criteria necessary to determine the validity of a scientific experiment

Eighth

- extends and refines use of criteria necessary to determine the validity of a scientific experiment.

Benchmark SC.H.3.3.1 - The student knows that science ethics demand that scientists must not knowingly subject coworkers, students, the neighborhood, or the community to health or property risks.

Grade Level Expectations

The student:

Sixth

- uses appropriate procedures for safety in the classroom, home, and community

Seventh

- uses appropriate procedures for safety in the classroom, home, and community

Eighth

- uses appropriate procedures for safety in the classroom, home, and community.

Benchmark SC.H.3.3.4 - The student knows that technological design should require taking into account constraints such as natural laws, the properties of the materials used, and economic, political, social, ethical and aesthetic values.

Grade Level Expectations

The student:

Sixth

- knows some ways that scientific discoveries create new technologies that affect society

Mini Rockets

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

combustion - a chemical change accompanied by the production of heat and light

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

proportion - a relationship between quantities such that if one varies then another varies in a manner dependent on the first

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

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.

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 both halves of a petri dish half full with water. This serves as a recycling water supply and spill control 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. Your teacher will add the chemicals to your micro-generators as follows:

   H_2 micro-generator:
   - 2 - 3 pieces of mossy zinc
   - hydrochloric acid (1.0 mole solution) to 10 cm from the top

   O_2 micro-generator:
   - hydrogen peroxide to 2/3 full
   - 10 - 20 drops of yeast water

5. Replace the lids and place in the petri dishes.
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.
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.
10. Your challenge is to find the optimum combination of hydrogen and oxygen for combustion (end product--rocket fuel!).
11. Record your observations below:

Parts (amount) H_2							
Parts O_2							
Rating							

12. Record your optimum fuel mixture here: ____

13. 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. Measure how far your rocket traveled.
Our rocket traveled: ____________________________

14. How could you increase the accuracy of your data and this experiment? ______________

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15 Why don’t the oxygen and hydrogen react as soon as they mix in the pipette bulb?

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Cleanup and Disposal

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