Rocket Science

Visitors collect hydrogen and oxygen gas in a tube and squeeze the mixture of gases into a flame, resulting in a small explosion.

OBJECTIVES:

Visitors learn that energy is sometimes the product of a reaction and that the energy can be controlled and used as power. They also learn that hydrogen might be a future source of clean energy to power automobiles.

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Procedure:

1. Always wear safety goggles. Caution: DO NOT TOUCH THE FLAME. IT IS VERY HOT. (If the flame goes out, tell a staff person immediately.)

2. Observe the solutions in the two test tubes. If the solutions are not actively bubbling, contact an OMSI staff person.

3. Hold a small plastic bulb, open end up, under the surface of the water in the beaker. Squeeze the bulb several times to push out the air inside and fill the bulb with water. This is your rocket.

4. Read this entire step before doing it.
   - Place the open end of the bulb over the outlet of the “H₂ generator.” You should see hydrogen (H₂) gas bubbles fining the bulb.
   - When the bulb is about halfway full of hydrogen, remove it and place it over the outlet of the “O₂ generator.” Fill the rest of the bulb with oxygen (O₂) gas.

5. Carefully hold the bulb close to (but not touching) the flame of the burner. Squeeze the bulb.

6. Repeat steps 3 – 5 again but use different amounts of hydrogen and oxygen.
   What combination of hydrogen and oxygen produces the loudest pop? Hint: The reaction produces water.
What does simple water have to do with launching the space shuttle?

A Closer Look:

In this experiment, you produced an explosion (pop) by igniting a mixture of hydrogen (H₂) and oxygen (O₂) gases (the components of water). Hydrogen and oxygen combine to form water (H₂O) in a reaction that produces significant energy. The explosive reaction between hydrogen and oxygen powers the rockets that launch the space shuttle. Hydrogen is also being studied as a clean-air fuel source for cars. Hydrogen fuel reacts with oxygen in the air and produces just energy and water.

In this experiment, hydrochloric acid (HCl) and zinc metal (Zn) generate the hydrogen gas and a by-product, zinc chloride (ZnCl₂). A reaction of hydrogen peroxide (H₂O₂) and
a catalyst generates the oxygen gas \((O_2)\) with water \((H_2O)\) as a by-product.
MATERIALS
(with amounts to have on hand)
- 6-8 15-mm by 100-mm test tubes
- 6-8 1-hole rubber stoppers (size 0)
- One 100-ml plastic beaker
- One large glass bowl
- One 600-ml beaker
- 4-6 small plastic pipette bulbs
- 6-8 micro pipette tips
- two mason jars
- two mason jar lids with two test-tube sized holes
- Two sponges cut to fit bottom of mason jars
- One fine-mesh strainer
- Manganese dioxide (MnO₂) chunks (keep 20 g on hand)
- Granular zinc (Zn) (keep 20 g on hand)
- Two 250-ml squeeze bottles
- One large plastic bottle with lid (for waste HCl)
- 200 ml 1.0M HCl (hydrochloric acid) (keep 500 ml on hand)
  OR — 200 ml of concentrated HCl
- 200 ml 3% H₂O₂ (hydrogen peroxide) (keep 500 ml on hand)
  OR — 100 ml of 30% H₂O₂
- One bunsen burner with rubber tubing (from general storage)
- Protective Plexiglas barrier (to place in front of the bunsen burner and over the gas valve)
- Vertical Plexiglas display stand, 8½ in. wide by 11 in. high
- Piece of black paper, 8½ in. by 11 in.
- Handheld spark generator such as a piezo lighter (from general storage)

Setup/Takedown Procedures

ORIGINAL SETUP
- Label four of the test tubes “H₂ Generator” and the other four “O₂ Generator.”
- Make spouts from the mid tips of the micro plastic pipettes (with bulbs removed) inserted into the holes of the eight rubber stoppers. Insert each stopper into the top of a test tube.
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- Label one mason jar with lid “H₂ Generators”, label the other one “O₂ Generators”
- Label the large glass bowl “Water.”
- Label the 100-ml beaker “bulbs”
- Label one 250-ml squeeze bottle “1.0M Hydrochloric Acid (HCl).”
- Label one 250-ml squeeze bottle “3% Hydrogen Peroxide (H₂O₂).”
- Label large plastic jar with lid “Waste HCl”
- Attach “CAUTION, HOT!” label to the Plexiglas barrier for the bunsen burner.
- Place the black paper in the vertical Plexiglas display stand.
- Prepare a sign: “SHUT OFF THE GAS at the end of the day: Put the Bunsen burners away; shut off the gas ON TOP AND BELOW.” Mount it on a red background and laminate it. Prepare the sign to be hung on the outside of the cabinet doors with string or wire and clips.

**WEEKLY SETUP**

- Get the Bunsen burner and tubing from general storage.
- Hang the laminated “SHUT OFF THE GAS” sign on the outside of the cabinet door.
- Hook up the Bunsen burner and tubing to the gas source.
- Place the Plexiglas barrier with the “CAUTION, HOT!” sign so that the gas handle is not accessible to visitors and the Bunsen burner is behind the edge of the barrier (so visitors won’t inadvertently burn themselves).

**Safety Precaution:** Place the vertical Plexiglas display stand with the sheet of black paper a few inches behind the Bunsen burner so that visitors will be able to see the flame. (Otherwise, the flame can be invisible.)

- Check to see if H₂ and O₂ generators need to be prepared (see Materials Prep) (keep 4 of each prepared).
- Prepare “rockets” if needed (see Materials Prep) (keep 9 on hand).

**DAILY SETUP**

- On a tray, set out the following:
  - Labeled mason jars with a sponge in bottom of each
  - A small labeled beaker with 3-6 bulbs or “rockets”
  - Labeled water bowl
- Get a bottle of 3% H₂O₂ (hydrogen peroxide) from the refrigerator.
Place the strainer and two filled squeeze bottles labeled “Hydrochloric Acid” and “Hydrogen Peroxide” so they are easily accessible but not within reach of visitors.

Fill the large glass bowl ⅔ full with water.

Prepare new “rockets” if you have fewer than three spares on hand (see Materials Prep).

JUST BEFORE THE LAB OPENS:

Activate the generators as follows:

- Fill one “H₂ Generator” test tube to the marked line with 1.0M HCl (hydrochloric acid). Insert a stopper. Add more Zn if necessary.
- Fill one “O₂ Generator” test tube to the marked line with 3% H₂O₂ (hydrogen peroxide). Insert a stopper. Add MnO₂ if necessary.
- Place the tubes in the labeled mason jars.

Note: You will need to activate new generators about every 15-20 minutes (when the old generators stop rapidly bubbling). To recycle old generators, see Running Suggestions.

Light the Bunsen burner as follows:

- Get the spark generator from general storage.
- Turn on the gas valve under the counter.
- Turn on the countertop gas valve and immediately light the Bunsen burner. Be sure the flame is going.
- Position the Plexiglas shield in front of the Bunsen burner. Be sure the “CAUTION, HOT!” label is attached to the shield.
- Position the Plexiglas display shield with black paper a few inches behind the Bunsen burner.

DAILY TAKEDOWN

Drain all liquid from all of the test tubes by holding the strainer firmly over the open end of the test tube to save reusable solids.

Drain HCl into waste container, DO NOT POUR HCl IN THE SINK.

Dump water from bowl, squeeze out sponges from mason jars and set to dry.

PUT THE H₂O₂ BACK IN THE REFRIGERATOR. (Store it in a regular storage bottle, not in the squeeze bottles.)

Turn off the gas valves on the counter and under the counter.

WEEKLY TAKEDOWN

Return the bunsen burner, rubber tubing, Plexiglas shield and tray to general lab storage.
☐ Return the “SHUT OFF THE GAS” sign to the tub (from the cabinet door).
◊ Watch small or mischievous children around the Bunsen burner.
◊ KEEP AN EYE ON THE BUNSEN BURNER FLAMES! If the flame goes out, turn off the gas immediately. If you do not smell gas fumes, relight the Bunsen burner. Flame goes out after almost every rocket, so check every time you hear a “pop”.
◊ The zinc will eventually be used up, so you may need to add more to the test tubes every so often.
◊ You will need to keep an eye on this experiment to be sure the solutions remain bubbling (they should continue to bubble adequately for 10-15 minutes after you add the solutions).
◊ Visitors may call a staff person if the solution is not bubbling. When called, you need to:
  □ Double-check the test tubes to make sure the bubbling really has slowed down. If it hasn’t, tell visitors that it should work but to call you again if they experience trouble. Invert test tubes once or twice to mix contents.
  □ If the generators are no longer actively bubbling, recycle the generators as follows:
    • Remove the test tubes from the plastic beaker.
    • Drain the liquid from the O₂ generator into sink, and liquid from H₂ into the waste beaker by holding the strainer firmly over the open end of the test tube (both solids are reusable and should stay in the test tubes).
    • Refill tube with new liquid.
  □ To activate new generators, follow the instructions in daily setup.
◊ Visitors might dump out the solids from the test tubes, so check the test tubes periodically.
◊ If visitors are not getting a pop, watch their technique. If they have decent technique, they should hear a good pop from a 50/50 mixture of hydrogen and oxygen.
◊ When tube is full, visitor must keep it inverted (open end down) because these gases are lighter than air, and will escape if bulb is turned up. They should also move bulb from generator to flame relatively quickly. Holding the bulb for a long time lets the gases escape. Another reason they might not work is if the visitor is not holding the bulb close enough to the flame when squeezing. It must be VERY CLOSE to the flame, but not in it.
Resist visitor requests for a larger bulb or other mixing containers - larger explosions can become dangerous. Likewise, watch out for the use of unauthorized containers by overly zealous visitors.

Ideally, the loudest pop comes from 2 parts hydrogen to 1 part oxygen, but the visitors may experience a slight variation from this. (It is very hard to measure the gases precisely.)

Encourage visitors to squeeze gases out near the tip of the flame, as this is the hottest part (also they are less likely to blow out the flame if they squeeze near the top).

Space-shuttle rockets use excess hydrogen to ensure complete combustion of the oxygen, which is much more massive than the hydrogen. The extra hydrogen contributes to thrust when it is later ejected (along with the products of combustion).

If you have access to a Tesla coil, you can launch visitors’ rockets. Ask the visitors to fill the bulb with the amount of hydrogen and oxygen they think will give the loudest pop. Place the full bulb over the end of the nail on the launch pad. Bring the Tesla coil near the tip of the nail and create a spark. The spark should set off combustion and the bulb should fly off the nail.

HCl (hydrochloric acid) and H₂O₂ (hydrogen peroxide) are hazardous substances; follow the handling and disposal instructions. Consult the Material Safety Data Sheets (MSDS) for additional information.

**SAFETY & DISPOSAL**

**MATERIALS PREP**

To prepare a “rocket”:
- Cut the bulb and about 0.5 cm of the barrel from a plastic micro pipette.
- Keep at least nine prepared bulbs on hand.

To prepare O₂ generators:
- Fill each O₂ generator test tube with about ¾ in. of MnO₂ (manganese dioxide).
- Fill the rest of the way with 3% H₂O₂

To prepare H₂ generators:
To prepare 1.0M HCl (hydrochloric acid):

- Fill each H₂ generator test tube with about ¾ in. of granular Zn (zinc), 20 mesh or larger.
- Fill tube the rest of the way with 1 M HCl

**CAUTION:** Concentrated hydrochloric acid is extremely corrosive. Handle it with care. Wear protective gloves, apron, and eyewear. Use it only in the fume hood. Avoid contact with skin or clothing. Neutralize any spills with baking soda and clean them up with large amounts of water.

**CAUTION:** A large amount of heat will be evolved after you mix HCl with water. Do not handle the beaker until it has cooled.

- Turn on the fume hood.
- Wear protective eyewear, chemical safety gloves, and an apron or lab jacket.
- In the fume hood, measure 83 ml of concentrated (12.1M) HCl (hydrochloric acid).
- Add the acid to 917 ml of dH₂O (deionized water) to make one liter.
- Store the extra solution in labeled/dated bottles in the acid cabinet.
- Turn off the fume hood.

To prepare 3% H₂O₂ (hydrogen peroxide):

**CAUTION:** 30% hydrogen peroxide is a strong oxidizer. Handle it with care. Wear protective eyewear, gloves, and an apron. Use it only in the fume hood. Avoid contact with skin and clothing. If contact occurs, wash affected area with copious amounts of water.

- Turn on the fume hood.
- Wear protective eyewear, chemical safety gloves, and an apron or lab jacket.
- In the fume hood, measure 25 ml 30% H₂O₂.
- Add 225 ml dH₂O (deionized water).
- STORE THE SOLUTION IN A LABELED/DATED BOTTLE IN THE REFRIGERATOR. (Do not store it in a squeeze bottle.)