

2008  
Winning Lesson Plan  
from Laguna Beach,  
California

*Launching Hydrogen-  
Powered Soda Bottle  
Rockets*

by Steven Sogo  
Laguna Beach High School

Subject: Chemistry  
Grade Level: High School  
Duration: One Week

## Introduction

This lesson plan, entitled “Launching Hydrogen-Powered Soda Bottle Rockets” is suitable for high school chemistry classes and involves 1 week of instructional time.

## Overview and Purpose

Students will create hydrogen and oxygen gases through two distinct reactions (one for hydrogen, a second for oxygen). Students will utilize gas laws and stoichiometric calculations to create the precise ratio of gases needed for maximum energy release in the rocket. In this project, students will learn about exothermic reactions, the importance of activation energies, and apply the kinetic molecular theory of gases.

## Educational Standards Addressed

[stoichiometry, \(standards 3a, 3d, 3e\)](#). Students know how to describe chemical reactions by writing balanced equations, how to convert the mass of a molecular substance to moles, and how to calculate the masses of reactants and products in a chemical reaction.

[Gases and their properties \(standards 4a, 4c\)](#). Students know the random motion of molecules and their collisions with a surface create the observable pressure on that surface and how to apply the gas laws to relations between the pressure, temperature, and volume of an ideal gas.

[Chemical Thermodynamics \(standard 7b\)](#). Students know chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.

[Reaction rates \(standard 8c\)](#). Students know the role a catalyst plays in increasing rxn rate.

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## Larger Context of Study

This lesson is best placed in a unit on gas laws after students have studied chemical energy (or in a unit on chemical energy after students have studied gas laws).

## Objectives

Build a rocket that will fly ~40 feet into the air.

## Materials

- 2-liter soda bottles
- calcium metal
- 10% hydrogen peroxide (~30% peroxide can be obtained from swimming pool supply stores)
- aluminum foil
- 12-volt transformer

## Innovation

This instructional plan is innovative because it requires students to apply their knowledge to do some real chemistry. Many chemistry students treat stoichiometry as an exercise in pushing numbers around on paper, but in this project, stoichiometry is an essential tool for creating a successful rocket. In addition, students can see how gas laws, energetics, and stoichiometry intertwine to create the unified science of chemistry.

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## Procedures

The rocket project is designed to be accomplished in 1 week. At my current school, our schedule affords 55-minute class periods on Monday, Tuesday, and Wednesday followed by 100-minute block periods on Thursday and Friday. The lesson plan I describe is formatted to fit this time schedule.

### Pre-lab (week before the rocket project)

To introduce “rocket week”, the teacher can present a video of past rocket launches (student filmed and edited). The teacher asks students to search their homes for bottles between 1 and 4 liters to use for their rockets. To create a rocket that flies, a student will need a soda bottle (built to withstand pressure). Use of a juice bottle or milk jug will result in a “rocket” that explodes on the launch pad, but does not rise into the air (some students prefer this effect—the destruction of the bottle can be rather exciting).

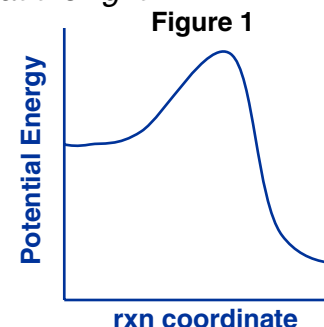
### Monday

Students should come into class with their bottles in hand (one bottle for each lab group). The teacher will hand out the *instruction packet* (presented here on pages 6–10), which guides students through the steps needed to load the rocket with a proper mixture of hydrogen and oxygen gases. Students are expected to work in lab groups and reach consensus on the proper calculations for the bottle that they are using. Teacher circulates from group to group, monitoring student progress and making suggestions if students are having difficulty with the calculations. Students should complete at least half the packet (up through question 4c) on this first day of the project. The remaining parts of the packet may be completed on Tuesday or Wednesday.

### Tuesday

The teacher will present a lesson on the nature of activation energy and the role of a catalyst. To introduce the concept, teacher will take a 5-cm strip of magnesium metal and ignite it using a Bunsen burner flame. A bright light and lots of heat are produced in this reaction. *Safety note: To avoid retinal damage, students should be instructed to avoid staring at the light.*

The discussion of this reaction should lead students to conclude that there are two components to the energy profile of this reaction—an initial endothermic phase (when energy from the Bunsen burner is used to ignite the magnesium) and a subsequent exothermic phase (when the bright light and heat are produced). Therefore, the energy profile for the reaction rises to a peak and then drops, as shown in Figure 1.



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## Procedures (Cont'd)

### Tuesday (Cont'd)

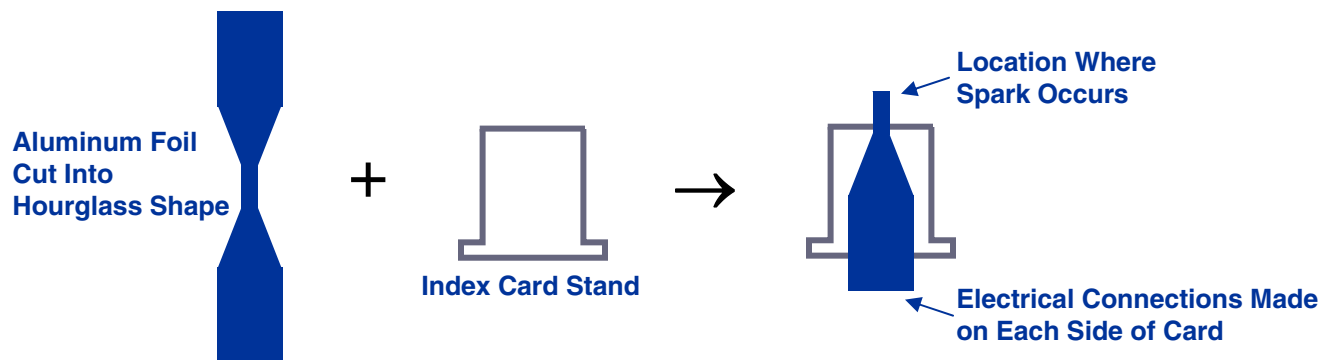
The teacher should label the energy profile appropriately, emphasizing the **Activation Energy** barrier. The discussion should communicate to students that this barrier can prevent a reaction from occurring (i.e. if the molecules can't get over the mountain, no reaction occurs). The discussion should then proceed to methods that a chemist can use to solve the problem of a reaction that cannot proceed due to a large activation energy barrier.

1. A chemist can provide energy to reactant molecules so they can surmount the barrier.
2. A chemist can introduce a catalyst, which decreases the height of the barrier so that reactants do not need tremendous amounts of energy to surmount the barrier.

These concepts can be effectively demonstrated using a rubber band-powered marble shooter and a 5 foot length of clear  $\frac{3}{4}$ " diameter plastic tubing. The plastic tube can be bent into a path that rises and then falls, symbolizing an energy profile with an activation energy barrier. The marble shooter provides energy (symbolizing thermal energy available to reactant molecules). When the marble is shot through a pathway that has a high barrier, the marble can't make it over the hill—either a more powerful marble shooter or a lower energy barrier is required.

### Wednesday

The teacher demonstrates to students how to build an electronic igniter for the rockets. A strip of aluminum foil is cut into a strip ~20 cm long and ~1.3 cm wide. This foil is cut to create an hourglass shape with the thin part about 2 mm wide. The fragile foil is supported with a piece of an index card cut to fit into the neck of the student's bottle. When electricity from a 12-volt transformer is passed through this foil, a spark will be created at the apex of the igniter. This spark is sufficient to ignite a bottle filled with hydrogen and oxygen gases.



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Students should test-build an igniter and pass electricity through it to verify that it will work. Igniters are one-use only (the aluminum foil breaks when it sparks). Students need at least one well-made igniter for launch day.

### Thursday/Friday: Load and Launch day

The rockets are loaded with gases using the method of water displacement ( $O_2$  first,  $H_2$  second). Students use the quantities of reactants they have calculated in their instruction packets. The rockets are launched outside in an open area (e.g. sports field). The teacher will set up a launch pad made from a ring stand with ring clamps appropriate for the bottle sizes being used. Two 50' extension cords are used to get electricity from an outlet to the launch pad. For a given launch, the sequence of events is:

1. Position igniter on launch pad base (use tape to secure).
2. Carefully invert bottle in launch pad ring so that the igniter goes into the neck of the bottle.
3. Make electrical connections from 12-volt transformer to aluminum foil.
4. Students (and teacher) retreat to safe distance (~50 feet).
5. The extension cord is plugged in and the rocket will launch. If rocket fails to launch, the most likely cause is a poorly built igniter.

## Instruction Packet

### Chemistry Assignment #66: Launching Rockets Using Secret Fuel #1

*The "secret fuel" is a mixture of hydrogen and oxygen.*

#### Overview

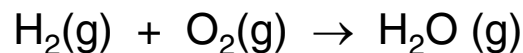
In the next lab block, we will be making hydrogen rockets using plastic bottles with volumes between 1 and 4 Liters. We will fill the bottles with a mixture of hydrogen gas and oxygen gas in an appropriate ratio. When ignited, the reaction will produce H<sub>2</sub>O gas at a very high temperature. The hot molecules will generate a propulsive force (or the bottle will simply blow up).

#### Note:

***Filling out these pages is your write-up for this lab. Do your work neatly and completely.***

#### Theory

1. The first thing to determine is the appropriate ratio of hydrogen and oxygen to use in your rocket. You need an explosive mixture to launch your rocket. A mixture too rich in hydrogen will burn quietly like a Bunsen burner instead of igniting explosively. A mixture too rich in oxygen will explode, but weakly. A mixture that is just right will produce maximum power for your rocket. The unbalanced equation for the propulsion reaction is as follows:



If you balance the equation shown above, you will know the correct **MOLE RATIO** of hydrogen to oxygen needed to achieve the maximum propulsive force.

2. Using the correct ratio of H<sub>2</sub> to O<sub>2</sub> you can start to figure out how much hydrogen gas and how much oxygen gas you will need to fill your plastic bottle. In the space below, sketch a picture of whatever size bottle you are using and draw a line showing how much of the bottle you will fill with hydrogen and how much you will fill with oxygen. Then translate this picture into actual volumes of hydrogen and oxygen (in liters).

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## Instruction Packet (Cont'd)

3. Use the **IDEAL GAS LAW** and your picture above to calculate how many **MOLES** of hydrogen you will need, and how many **MOLES** of oxygen you will need in your plastic bottle. Also give a one-sentence explanation for why 22.4 L/mole is NOT a valid ratio to use for this experiment. *Hint: What does STP actually mean?*

From page one, you know how much hydrogen and oxygen you need for your rocket, but you will have to **GENERATE** these gases by running chemical reactions. On this page and the next, you will figure out what quantities of reactants you will need to use to make the right amount of hydrogen and oxygen.

4. First you will do calculations for generating OXYGEN gas from H<sub>2</sub>O<sub>2</sub>. The unbalanced equation is:



This reaction is a decomposition reaction. The molecule on the left is hydrogen peroxide. It is inherently unstable, and will rearrange its atoms to form water and oxygen gas. This reaction is extremely slow at room temperature unless a catalyst is added. We will use the salt potassium iodide (KI) as a catalyst to hasten this reaction. *Note: When running the actual reaction, a small scoop of the catalyst (about 0.7 grams) will be “packaged” in weighing paper and then added to the hydrogen peroxide solution. You will place the stopper on the reaction flask and then shake to allow the catalyst to come out of its envelope. This method should enable you to collect -100% of the gases created in this reaction.*

- a) Balance the equation shown above and use stoichiometry to calculate the **MASS** of hydrogen peroxide needed to generate enough O<sub>2</sub> for your rocket. *Hint: Your calculation starts with the number of moles of O<sub>2</sub> you calculated in step #3.*

## Instruction Packet (Cont'd)

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- b) The hydrogen peroxide that you will use to generate oxygen gas will come to you in liquid form. This liquid is a solution of hydrogen peroxide diluted with water. The solution contains 10% hydrogen peroxide (the other 90% being water). Use your number from part (a) to calculate how many grams of this **SOLUTION** you will need to use. *If you don't know how to make the calculations required here, I suggest you start by drawing a picture of what the 10% solution of hydrogen peroxide will look like. Then label the fraction of the solution that you **KNOW** (The mass of  $H_2O_2$  calculated in part (a)).*
- c) Assuming that the 10% peroxide solution has a density of 1g/ml, convert the grams you calculated in (b) into milliliters of solution.
- d) **\*\***(save for later—your instructor will need to teach you some new ideas before you can do this problem) Sketch an energy profile for the **CATALYZED** and **UNCATALYZED** decomposition of hydrogen peroxide. Then explain the **SIGNIFICANCE** these energy profiles. *Note: The overall  $\Delta H$  for the reaction is -95 kJ per mole of  $H_2O_2$ .*

## Instruction Packet (Cont'd)

5. Hydrogen can be generated in many ways. We will use the method shown below:



- a) Balance the equation shown above and use  $\Delta H_f$  values to calculate  $\Delta H$  for the reaction.
- b) Use stoichiometric calculations to determine the **MASS** of calcium and **VOLUME** of water needed to produce enough hydrogen for your rocket. *Be neat! You'll need to remember the **DENSITY** of water.*
- c) The amount of water you have calculated is the amount that will actually react with the calcium you are weighing out. This will mean that in the end, your reaction will have zero liquid water remaining. This is **NOT** a good plan for this reaction. Try to give a couple of thoughtful reasons why it would be smart to add **EXCESS** water when you run this reaction. *Note: When you run the reaction, you will want to use a **LARGE** excess (as large as your reaction flask permits). In the margin of this paper, make a **SKETCH** of what your flask should look like if you use a large excess of water.*
- d) The calcium you will be using is a very reactive metal. Even while inside its jar, the outer surface of the calcium will be oxidized to some extent (forming CaO). This reduces the amount of actual calcium in the lumps that you will be using. How should you correct for this problem?

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