

# The Properties of Oxygen Gas

## Objectives

The objectives of this laboratory are:

- To generate (and collect) oxygen gas via the decomposition of hydrogen peroxide.
- To investigate the properties of oxygen, particularly as an agent of combustion.

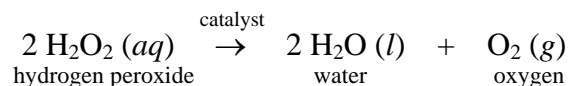
## Background

Oxygen is one of the most abundant elements on this planet. Our atmosphere is 21% free elemental oxygen. Oxygen is also extensively combined in compounds in the earth's crust, such as water (89%) and in mineral oxides. Even the human body is 65% oxygen by mass.

Free elemental oxygen occurs naturally as a gas in the form of diatomic molecules,  $O_2 (g)$ . Oxygen exhibits many unique physical and chemical properties. For example, oxygen is a colorless and odorless gas, with a density greater than that of air, and a very low solubility in water. In fact, the latter two properties greatly facilitate the collection of oxygen in this lab. Among the unique chemical properties of oxygen are its ability to support respiration in plants and animals, and its ability to support combustion.

In this lab, oxygen will be generated as a product of the decomposition of hydrogen peroxide. A catalyst is used to speed up the rate of the decomposition reaction, which would otherwise be too slow to use as a source of oxygen. The catalyst does not get consumed by the reaction, and can be collected for re-use once the reaction is complete. The particular catalyst used in this lab is manganese(IV) oxide.

Generating Oxygen Gas:



The oxygen gas produced will be collected in bottles by a method known as the downward displacement of water (see figure on page 3). Once collected, several tests will be performed in order to investigate the role of oxygen in several combustion reactions.

A combustion reaction is commonly referred to as "burning". During a combustion reaction, oxygen reacts chemically with the substance being burned. Note that since our atmosphere is roughly 21% oxygen, many substances readily burn in air. Both oxygen and the substance being burned (the reactants) are consumed during the combustion reaction, while new substances (the products) and heat energy are generated. Since heat is produced, this is an exothermic reaction.

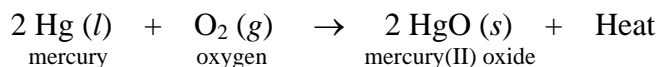
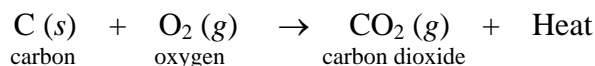
Combustion Reactions:



The actual products of a combustion reaction depend on what substance is burned and how much oxygen is present. In general, however, when a pure element burns in oxygen the product is called an oxide. An oxide is a compound containing both the element and oxygen chemically combined together.

Some examples of element combustion are shown below. Several such reactions will be performed using the oxygen gas collected in this lab.

Combustion of an Element:



## Procedure

### Safety

First, be sure to exercise caution when using the hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and the hydrochloric acid (HCl) as they can cause chemical burns and skin irritation. If either of these chemicals comes into contact with your skin, immediately rinse with water for a minimum of fifteen minutes and notify your instructor. Second, do not look directly at the burning magnesium. In addition to being very bright, it emits harmful UV radiation that could cause damage to the retina of your eyes.

### Materials and Equipment

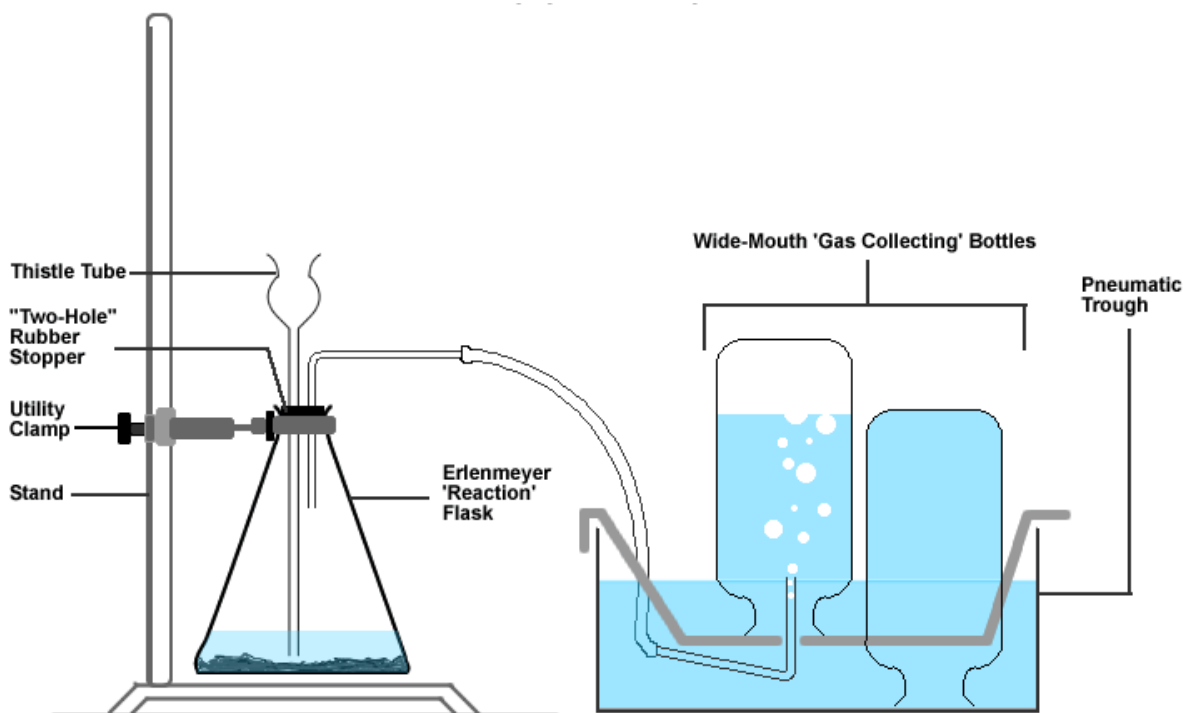
Materials: 9% Hydrogen peroxide solution, manganese(IV) oxide, wooden splints, candle, sulfur, steel wool, magnesium ribbon, zinc metal and 6M hydrochloric acid

Equipment: 250-mL Erlenmeyer flask, five wide-mouth bottles, four glass ‘cover’ plates, pneumatic trough, “stopper + thistle tube + tubing” apparatus\*, utility clamp, stand, deflagration spoon, crucible tongs, small beaker, medium beaker and a large test tube.

### Part A: Generating and Collecting Oxygen Gas

- Obtain the following equipment:
  - A 250-mL Erlenmeyer flask (locker)
  - The “two-hole stopper + thistle tube + glass tubing + rubber tubing” apparatus (stockroom)
  - Five wide mouth ‘gas-collecting’ bottles (under sink)
  - Four glass ‘cover’ plates (front desk)
  - A pneumatic trough (under sink) filled with water to ½ inch above the metal shelf
- Fill four of the five wide-mouth bottles *to the brim* with water (the fifth will be used later). Then gently slide a glass plate over the mouth of each bottle. Make sure that there are no air bubbles at the top of the glass plate.
- While holding the glass plate with your fore and middle finger, gently invert a bottle and lower it into the water in the pneumatic trough. Remove the glass plate when the mouth of the bottle is below the water level in the pneumatic trough. Repeat this for all four bottles. Place the glass plates aside on a paper towel, as they will be used later.
- Place one gas-collecting bottle on the metal shelf. Make sure that the mouth of the bottle does not come out of the water.

- Now focus on your reaction vessel, the Erlenmeyer flask. Add a pea-sized amount of manganese(IV) oxide (the catalyst) to the flask, followed by about 50-mL of tap water.
- Finally, assemble all your equipment together as demonstrated by your instructor, or as shown in the figure below. Make sure that
  - the end of the thistle tube is completely covered with water at the bottom of the flask,
  - the end of the glass tubing running from the Erlenmeyer flask is inserted under the opening in the bottom of the metal shelf into the gas-collecting bottle (which is full of water),
  - the Erlenmeyer flask is stabilized with a utility clamp.
- Obtain about 30-mL of 9% aqueous hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) in your smallest beaker. Then carefully add about 10-mL of this  $\text{H}_2\text{O}_2$  through the thistle tube. The generation of oxygen gas should begin immediately. If at any time the rate of the reaction in the Erlenmeyer flask appears to slow down, add another 10-mL portion of  $\text{H}_2\text{O}_2$ .
- The oxygen produced will fill the inverted bottle by displacing the water in it. This is because oxygen does not dissolve in water, due to its low solubility. When the first bottle is completely filled with gas, place the second bottle on the metal rack in its place and allow it to fill in a like manner. Repeat this for the third and fourth bottles.
- As soon as each bottle is completely filled, remove it by placing a glass plate under the bottle's mouth while under water, then lifting the bottle and plate from the pneumatic trough. Place the bottle on the lab bench ***mouth up*** and ***do not remove the glass plate***. Since oxygen is denser than air, it sinks to the bottom of the flask and will not readily leak out the top.
- Using masking tape, label each bottle of gas in the order they are collected: Bottle #1, Bottle #2, Bottle #3 and Bottle #4. Label the fifth unused empty bottle "Air Bottle".
- Once all four bottles are filled with oxygen, do not add any more  $\text{H}_2\text{O}_2$  to the Erlenmeyer flask. Set it aside and allow the reaction to go to completion. At the end of the lab, the chemicals remaining in the reaction flask and any unused  $\text{H}_2\text{O}_2$  must be disposed of in the labeled waste container in the hood. In the meantime, proceed to Part B.



## Part B: The Properties of Oxygen Gas

\*Dispose of all chemicals used in these tests as indicated by your instructor\*

### Test 1: Combustion of wood

Light a wooden splint, and then blow it out. While it is still glowing red, quickly insert the splint into Bottle #1 (oxygen-filled). How many times can you repeat this? Record your observations. Now re-light the same wooden splint, and again blow it out. Place it in the empty bottle (air-filled) while it is still glowing. Record your observations.

### Test 2: Combustion of candle wax

Place a small candle on a glass plate and light it. Then uncover and carefully lower Bottle #2 (oxygen-filled) over the candle. Measure and record the number of seconds that the candle continues to burn. Then re-light the candle lower the empty bottle (air-filled) over it. Again, measure and record the number of seconds that the candle continues to burn. Also be sure to record any other relevant observations.

### Test 3: Combustion of sulfur

***This test must be performed in the hood under instructor supervision.*** Take your Bottle #3 (oxygen-filled) and your empty bottle (air-filled) to the hood your instructor directs you to. Place a small lump of sulfur in a deflagrating spoon (located in the hood). Light the Bunsen burner in the hood, and heat the sulfur in the spoon. The sulfur will first melt, then burn with an almost invisible blue flame. Insert the spoon with the burning sulfur in Bottle #3 and record your observations. Then insert it in the empty bottle, and again record your observations. When finished, extinguish the burning sulfur in the beaker of water provided in the hood.

### Test 4: Combustion of iron

Pour about 20-mL of tap water into Bottle #4 (oxygen-filled) and replace the glass plate quickly. Take a loose, frayed out 2-3 centimeter piece of steel wool and hold it in a Bunsen burner flame for a very brief instant with your crucible tongs (it will glow red). Then immediately lower the steel wool into Bottle #4. Record your observations. Repeat with the empty bottle (air-filled) and record your observations.

### Test 5: Combustion of hydrogen

***This test must be performed in air only.*** (Note: The hydrogen burned in this test must be first generated by a reaction between zinc and hydrochloric acid.) To a large test tube, add 1-2 pieces of zinc metal followed by about 3-mL of hydrochloric acid. Rapid bubbling should begin immediately as hydrogen gas is produced, and the bottom of the test tube will get quite hot. Place the test tube in the medium beaker. After 60 seconds have elapsed, light a wooden splint. Do not blow it out. Hold the burning splint to the mouth of test tube (where the hydrogen gas is being evolved) and record your observations.

### Test 6: Combustion of magnesium

***This test is an instructor demonstration. It must be performed in air only.*** Hold a 1-inch piece of magnesium metal in a Bunsen burner flame with your crucible tongs until it ignites (in air). Record your observations, remembering not to look directly at the burning magnesium!