

## Experiment #9: The Preparation and Properties of Oxygen

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### Objectives

We will observe the thermal decomposition of several oxygen-containing compounds called oxides. We will collect molecular oxygen and demonstrate its reactivity with several chemical elements.

*Safety glasses are required for this experiment.*

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### Discussion

Oxygen is a plentiful and highly reactive element on the earth. Oxygen comprises about 21% of the earth's atmosphere. In its elemental form oxygen is a gas and diatomic.

#### Major Components in Earth's Atmosphere

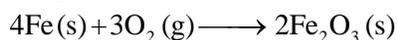
Gas	Percent Mass	Gas	Percent Mass
nitrogen	78.084	neon	0.00182
oxygen	20.947	helium	0.00052
argon	0.934	krypton	0.00010
carbon dioxide	0.033		

The earth's crust contains a large amount of oxygen as well, primarily in the form of silicates.

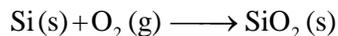
#### Elemental Abundances in Earth's Crust

Element	Percent Mass	Element	Percent Mass
oxygen	46.6	sodium	2.8
silicon	27.7	potassium	2.6
aluminum	8.1	magnesium	2.1
iron	5.0	others	1.5
calcium	3.6		

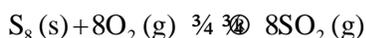
Many metals react with oxygen to form compounds called oxides. For example, iron reacts with oxygen to form iron(III) oxide (rust).



Metalloids will also react with oxygen. Silicon forms silicon dioxide, the main component of sand, when it reacts with oxygen:



Just as with metals and metalloids, the product of the reaction of oxygen with a nonmetal is an oxide. With nonmetals, the oxides formed are sometimes gaseous. For example, elemental sulfur ( $\text{S}_8$ ) reacts with oxygen to form sulfur dioxide, a poisonous gas that can be used as a food additive to sterilize dried fruit and wine.



Whether a metal oxide compound decomposes easily depends to a large extent on the strength of the metal-oxygen bonds. If the bonds are strong, a large amount of energy (high temperature) is required to break them. If they are relatively weak then the amount of energy required to break the bonds is smaller, and the temperature at which the compound decomposes is relatively low.

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**Part 1: Decomposition of oxygen-containing compounds**

Your instructor will demonstrate this part.

Each oxide listed below will be heated using a Bunsen burner. Describe the physical properties of these oxides. Physical properties include color, texture, and state of matter. Observe any changes that occur. Any changes in color, texture, gas formation, melting, etc., should be written in the data sheet.

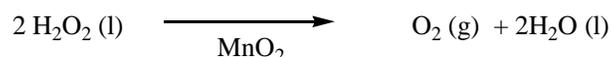
Name of Oxide	Chemical Formula	Physical Properties	Observations upon heating
Sodium nitrate	$\text{NaNO}_3$		
Silicon dioxide	$\text{SiO}_2$		
lead(IV) oxide	$\text{PbO}_2$		
Magnesium oxide	$\text{MgO}$		
Potassium chlorate	$\text{KClO}_3$		

In the space below, write chemical equations for each substance that released oxygen

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**Part 2: Collection of Oxygen over Water**

You will be collecting 3 bottles of oxygen which will be produced by the decomposition of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ). The following equation expresses the chemical change that occurs.



The oxygen is collected by a method known as downward displacement of water. The gas is conducted from a generator to a bottle of water inverted through a water-filled trough. The oxygen, which is only very slightly soluble in water, rises and forces the water out.

The rate of decomposition is accelerated using a catalyst, manganese dioxide.

**Procedure:**

Your apparatus will consist of a collecting trough that is connected by rubber tubing to a generator bottle with a thistle tube. The reaction will take place in the generator bottle and then the oxygen gas will move through the tubing into the collecting trough where the collection bottles will be.

1. Partly fill the collecting trough with water, making sure that the shelf is covered with water.
2. Fill three collection bottles with tap water and place all three in the collection trough upside down. The glass plate can be used to cover the opening of the bottles as you place them under the surface of the water in the trough. Each bottle should be filled with water and positioned upside down in the trough.
3. The generator bottle already contains the catalyst. You will be given 40 mL of hydrogen peroxide which you will add once you are ready to begin.
4. Once the peroxide has been added and bubbles start forming in the trough, wait a few seconds for all the air to be purged from the generator bottle and tubing.
5. Slide one of the collection bottles over the hole that the bubbles are passing through and hold the bottle down with one hand. As oxygen enters the bottle, it will displace the water, and the bottle will become buoyant. This could cause it to flip over.
6. Once almost all of the water in the bottle has been completely displaced, use one of the bottle lids to trap the oxygen in the bottle. You want to have a small amount of water (2-3 mL) in the bottle before you cap it. Slide a second bottle over the hole and collect more oxygen. Fill it with oxygen as you did with the first bottle. Continue with the third bottle.

The bottles will be used in part 3 of this procedure.

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**Part 3: Preparation of Oxides, Formation of Acids and Bases from Oxides**

As stated earlier, oxygen is a reactive element. To demonstrate this idea we will use the oxygen collected in Part 2 to react with elemental sulfur, phosphorus, magnesium, iron and charcoal. In each case, the reaction will produce an oxide.

**Procedure**

1. Label one of your collection bottles "sulfur." Label the second bottle "phosphorus." The third bottle will be used for class demonstrations.
2. Bring the bottle labeled "sulfur" to a fume hood. Your instructor will place a small amount of sulfur in a deflagrating spoon. Using the Bunsen burner, the sulfur will be heated until it starts to burn. Quickly open the bottle containing oxygen, and quickly place the spoon into the bottle. Allow the sulfur to burn in the oxygen-enriched atmosphere. Replace the lid onto the bottle. Shake the solution in the bottle. Take the bottle back to your work station.
3. Repeat the same procedure using phosphorus and the bottle labeled "phosphorus."
4. Place two drops of universal indicator solution (UIS) in each of the bottles labeled "sulfur" and "phosphorus". Record the color of the solution in each bottle.
5. Your instructor will demonstrate the remaining three elements.

Complete the following table:

Oxide	Color of Solution with UIS	Color of solution with Phenolphthalein
$\text{Fe}_2\text{O}_3$		
$\text{CO}_2$		
$\text{SO}_2$		
$\text{P}_4\text{O}_{10}$		
$\text{MgO}$		

In the space below, write balanced equations for the reaction of each element with oxygen.

Write equations for each oxide with water:

Can you suggest a generalization for acids and bases, based on your observations?

a) Oxides of metals, if dissolved in water, produce \_\_\_\_\_

b) Oxides of nonmetals, if dissolved in water, produce \_\_\_\_\_