# EXPERIMENT 8
# The Preparation and Properties of Oxygen

## Objective

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. * * ****

## Equipment and Materials

Solid samples of sodium nitrate, sand (silicon dioxide), lead (IV) oxide, magnesium oxide, and potassium chlorate in test tubes. Potassium chlorate mixed with manganese dioxide in a large test tube, oxygen collection apparatus with three collection jars, solid phosphorus, solid sulfur, magnesium ribbon, universal indicator, and phenolphthalein.

## 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 | | |

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): $4Fe\,(s) + 3O_2\,(g) \rightarrow 2Fe_2O_3\,(s)$

**Metalloids** will also react with oxygen. Silicon forms silicon dioxide, the main component of sand, when it reacts with oxygen: $Si\,(s) + O_2\,(g) \rightarrow SiO_2\,(s)$

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 (**$S_8$**) reacts with oxygen to form sulfur dioxide, a poisonous gas that can be used as a food additive to sterilize dried fruit and wine.

$S_8$ (s) + $8O_2$ (g) → $8SO_2$ (g)

Whether a metal oxide compound decomposes easily depends largely 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 the bonds are *relatively weak*, a *smaller amount of energy* (lower temperature) is required to break them, i.e. the temperature at which the compound decomposes is relatively low.

# Procedure

## PART 1: DECOMPOSITION OF OXYGEN-CONTAINING COMPOUNDS

Your instructor will demonstrate this part.

Each oxide listed below will be heated using a Bunsen burner. As your instructor presents each case, observe and describe the physical properties of these oxides prior to heating. Physical properties include ***color***, ***texture***, and ***state of matter***. Thoroughly observe any changes that occur. You must record whether or not there is any change, along with any of the changes in color, texture, gas formation, melting, etc., all in the data sheet below.

| Name of Oxide | Chemical Formula | Physical Properties | Observations upon heating |
|---|---|---|---|
| **Sodium Nitrate** | **$NaNO_3$** | | |
| **Silicon Dioxide** | **$SiO_2$** | | |
| **Lead(IV) Oxide** | **PbO2** | | |
| **Magnesium Oxide** | **MgO** | | |
| **Potassium Chlorate** | **$KClO_3$** | | |

**In the space below, write the chemical reaction equations <u>for each substance *that released oxygen*</u>:**

## 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*** (**$H_2O_2$**). The following equation expresses the chemical change that occurs:

$$2\,H_2O_2\,(l) \xrightarrow[MnO_2\ (catalyst)]{} O_2\,(g) + 2H_2O\,(l)$$

The oxygen is collected by a method known as *downward displacement of water*. The gas is conducted from a generator to an inverted bottle of water 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 connects via 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 tap water, making sure the shelf is *under* the water level.
2. Fill **3** collection bottles with tap water. Use the accompanying glass plate to cover a bottle, invert the bottle and place it into the trough upside down. Repeat with the remaining bottles. * * ***Before moving on to the next step***, make sure each bottle is *entirely* filled with water upside down in the trough.
3. The *generator bottle* already contains the catalyst (**$MnO_2$**). Once your instructor confirms your setup, ***AND*** that you are wearing lab gloves, you will receive 40 mL of hydrogen peroxide (**$H_2O_2$**). When instructed to begin, add your $H_2O_2$ **s l o w l y**.
4. Once 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, and ***you will have to start over with that bottle*** if so.
6. Once the bottle fills *almost* entirely with oxygen, you will use one of the bottle lids to seal all of the gas in the bottle. You want to have a small amount of water (2-3 mL) in the bottle before you cap it. The way to do this is lift the bottle straight up without turning it, slide the lid underneath, and close it. ***Only after sealing the bottle*** will you set it aside. Repeat **5** and **6** with the remaining two bottles.

*** * *** **WAIT** for your instructor to indicate when to start Part 3, which requires all **3** bottles.

## 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***, and ***magnesium***. In each case, the reaction will produce an **oxide**.

### PROCEDURE

1. Label one collection bottle "**sulfur**." Label the second bottle "**phosphorus**." Your instructor will use the third bottle 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 over the bottle opening. 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 workstation.
3. Repeat the same procedure (step 2) using phosphorus and the bottle labeled "**phosphorus**."
4. Your instructor will place **two drops** of ***universal indicator solution*** (UIS) in some of each "sulfur" and "phosphorus" bottle. Record the resulting color (ROYGBIV) of the solution in each bottle.
5. Your instructor will demonstrate the remaining three elements.

**Record Part 3 Observations Below:**

| Oxide | Color of Solution with UIS | Color of solution with Phenolphthalein |
|---|---|---|
| $SO_2$ | | |
| $P_2O_5$ | | |
| $MgO$ | | |
| $CO_2$ | | |
| $Fe_2O_3$ | | |

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

**Now, *write balanced equations* for the reaction of each *oxide* with *WATER*:**

**Based on your observations, suggest a generalization for acids and bases:**

a) Oxides of ***metals***, if dissolved in water, produce ___________________________

b) Oxides of ***nonmetals***, if dissolved in water, produce ____________________________