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**Purpose:** To learn about the properties of oxygen.

**Learning Objectives:**
1. Learn about the role oxygen plays in fire
2. To learn how to calculate the amount of oxygen in the atmosphere
3. To understand the process that creates rust

**Next Generation Science Standards (est. 2013):**
- PS1.B: Chemical Reactions
- PS3.D: Energy in Chemical Processes and Everyday Life (partial)
- LS2.B: Cycles of Matter and Energy Transfer in Ecosystems (partial)
- ESS2.A: Earth Materials and Systems (partial)
- ETS1.A: Defining Engineering Problems
- ETS1.B: Designing Solutions to Engineering Problems
- ETS1.C: Optimizing the Design Solution

**National Science Education Standards (valid 1996-2013):**
- Physical Science Standards: Properties and changes of properties in matter
- Earth and Space Science Standards: Structure of the earth system

**Grade Level:** 2-8

**Time:** 60 minutes

**Materials:**
- Safety glasses
- Work gloves (for handling steel wool)
- Test tubes
- Beakers
- 100mL graduated cylinders
- 15mL graduated cylinders
- 3% hydrogen peroxide
- Manganese dioxide
- Tea-light candles
- Matches

- Spatulas
- Wooden splints
- Waste bucket for burnt materials
- Vinegar
- Baking soda
- 00 grade steel wool
- Balance that measures up to 14.3 grams. (Usually cost about $15)
Safety:
1. Students should wear safety glasses during all activities.
2. Students should not be allowed to use matches or candle.
3. Students should be cautioned to only mix the chemicals as directed.
4. Large pieces of dry ice may chill water until a layer of ice forms around the dry ice. The dry ice will continue to sublimate until the ice pops, and pieces of ice and/or dry ice may be ejected from the cup. Prevent this by using small pieces of dry ice, and monitoring the dry ice in the cup.

Preparation ahead of time:
Prepare small bottles of MnO\textsubscript{2} and 3%H\textsubscript{2}O\textsubscript{2} for student use.

Introduction:
Air refers to the mixture of gases that make up the Earth’s atmosphere. Most of the gas in air is nitrogen. Nitrogen is odorless, colorless, tasteless, and mostly inert. The next most prevalent gas in Earth’s atmosphere is oxygen. Oxygen is also colorless, odorless, and tasteless, but it is the gas that is essential to all living animals. When we inhale, our lungs draw oxygen out of the air. It gets transferred to our blood, which moves the oxygen throughout our bodies to fuel the many chemical processes that take place every second.

Procedures:
1. Oxygen and Flame
   a. Students and instructor should wear safety goggles.
   b. Have a student measure 10 mL of hydrogen peroxide in a graduated cylinder and pour it into a test tube. Tell students that hydrogen peroxide breaks down into water and oxygen gas.
   c. Allow students to use a spatula to pull a tiny amount of manganese dioxide out of the vial (about the same size as a grain of rice). Put the manganese dioxide into the test tube with the hydrogen peroxide.
   d. Have students make observations. They should notice the mixture begins to bubble, they may notice fog, the test tube may warm noticeably.
   e. Light a tea-light candle.
   f. Hold a wooden splint in the candle until it is burning well.
   g. Gently blow out the splint. (Do not wave the splint, as this may cause pieces to break off.) The splint should remain glowing red on the tip, but not flaming. If it stops glowing, you can repeat the process.
   h. Ask the students to make observations as you put the glowing splint into the mouth of the test tube. The splint should burst into flames. If not, steps d-g may have taken too long. Have the students rinse out the test tube and repeat the process.
i. If you remove the splint quickly and blow it out, you can repeat several times before the hydrogen peroxide is consumed.

j. Students should repeat this procedure with baking soda and vinegar in the test tubes to determine if the gas produced by that reaction is oxygen. (However, instructor must light the splint.)

2. Carbon Dioxide and Flame
   a. Light a tea-light candle and place it in the bottom of large beaker.
   b. Have a student measure and pour 15mL of vinegar carefully down the side of the beaker so that the candle remains lit.
   c. Have another student carefully shake a small amount (about a gram) of baking soda into the vinegar using a powder funnel or a piece of folded paper.
   d. Have students observe the results.
   e. Students can also use tall graduated cylinders for baking soda and vinegar reaction and then pour out the CO₂ gas (but not reaction solution) onto the candle.

3. Determining Oxygen Content in Atmosphere
   a. Have students use work gloves to separate a small portion of steel wool (about the size of a piece of gum). The steel wool should be spread out to maximize volume, not balled up.
   b. Have students record the mass of the steel wool (to as many decimals as possible.) Discuss mass, grams, and decimals with students, if necessary.
   c. Have the student soak the steel wool in some vinegar for a few seconds.
   d. Using a pencil or other implement, have the students place the steel wool at the bottom of a test tube.
   e. Have the student put 10-15mL of water in a graduated cylinder.
   f. Allow the student to drop the test tube upside down into the graduated cylinder. The test tube should be full of air (and steel wool.) Have the student retry if air escapes the test tube.
   g. Wait 20-25 minutes (move on to flashcards activity).
   h. Observe any changes.
   i. Using the graduations on the cylinder, have the student measure how far the water has traveled up the test tube and how tall the test tube is.
   j. Remove the test tube and withdraw the steel wool. If necessary, allow to dry before remassing. (Do not wipe it dry!)
   k. Allow students to make more observations and predict the mass of the steel wool.
   l. Remass the steel wool.

4. Create Your Own Investigation
   a. During discussion, allow students to develop a testable question.
i. This may be similar to a previous activity, changing one variable, such as, what happens if the steel wool is balled up? Not soaked in vinegar? Underwater? etc.
b. Guide the students in devising a way to test their question.
c. Have students do investigation and summarize the results.

5. Flash Card Questions
a. What is rust?
i. Iron atoms chemically react with oxygen atoms.
b. What is the chemical symbol for iron?
i. Fe
c. What is air?
i. A mixture of gases.
d. Name two gases in the air.
i. Nitrogen, oxygen, carbon dioxide, water, argon.
e. What is the fire triangle?
i. It describes the three things needed for a fire.
f. What are the three items in the fire triangle?
i. Oxygen, fuel, heat.
g. What is a catalyst?
i. It speeds up a reaction but is not used up by the reaction.
h. What is created when hydrogen peroxide breaks down?
i. Oxygen and water.

Discussion:

Oxygen
Ask students if they are familiar with hydrogen peroxide. Tell them that it is commonly found in medicine cabinets. It works as an antibacterial agent. They may have experienced it being poured over wounds. Tell them that hydrogen peroxide has two oxygen atoms in each hydrogen peroxide molecule, and that the molecules break down. The atoms rearrange into oxygen gas and water. The process will happen faster if a catalyst, like manganese dioxide is used. Catalysts speed up reactions, but are not used by the reaction. An analogy is a brick sliding down an inclined plane.1 If the surface is rough, the brick might not make it down the entire incline, even though gravity is still pulling it. However, if a layer of ice (or other smooth substance) is placed over the inclined plane, the brick will easily slide down. The ice does nothing to affect the mass of the brick, height of plane, force of gravity, or overall outcome.

Remind students about the fire triangle. Describe how oxygen helps things to burn. Using this characteristic of oxygen can be helpful to identify it, since it is a colorless, odorless gas. Solicit from the students other facts they know about oxygen. They may recall that animals' lungs breathe in air and remove some oxygen from it. The oxygen is then bound to hemoglobin proteins in red blood

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cells and circulated throughout the body. They also may recall that oxygen is a product of photosynthesis and it is expelled from plants.

Oxygen combines with iron to form rust. Steel wool is finely divided iron. Because of the increase in surface area (and cleaning with vinegar beforehand) the steel wool will quickly rust. The reaction will be limited by the amount of oxygen available in this activity. As the oxygen gas is consumed, the amount of air in the test tube decreases. Air is comprised of about 21% oxygen. As the gas in the test tube decreases, the surrounding air pressure pushes the water up into the test tube. The proportion of air used to air remaining can be used to mathematically determine the proportion of oxygen in air. Upon taking the final mass of the steel wool, students should find that it weighs more. This may surprise students (even after considering the above equation) because rust is considered a destructive process. Rusting actually increases an object’s mass because of the oxygen that is added. (A more general name for rusting is oxidation. Rust specifically refers to oxidized iron.) However, rust is crumbly and erodes quickly, compared to the strength and durability of iron. To prevent this, iron objects are often coated in zinc (which does not rust.)

**Carbon Dioxide**

The addition of baking soda to vinegar produces carbon dioxide. The carbon dioxide will suffocate the flame. Students may be familiar with the “fire triangle”, which relates fuel, oxygen, and heat as the three elements necessary for a fire. The presence of carbon dioxide restricts the oxygen available to the flame. Some fire extinguishers employ carbon dioxide.

**Evaluation:**

Name two characteristics of oxygen.
Is oxygen explosive?
What do you need to form rust?
Are rusting and oxidation the same?
Is carbon dioxide explosive?