Where There's Fire There's...

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In this Activity, students compare the combustion of different substances—a glowing wooden toothpick and lit birthday candle—in air, oxygen, exhaled breath, and carbon dioxide atmospheres. The oxygen and carbon dioxide are generated from supermarket chemicals.

Background

Household bleach (6% sodium hypochlorite, NaOCl) and hydrogen peroxide (3% H_2O_2) are used to generate oxygen according to the equation:

$$NaOCl(aq) + H_2O_2(aq) \rightarrow O_2(g) + H_2O(l) + NaCl(aq)$$

An excess of hydrogen peroxide ensures complete reaction of the sodium hypochlorite. A ratio of 2 tsp (10 mL) of bleach and 3 tsp (15 mL) of 3% hydrogen peroxide for each 4 oz (~120 mL) of volume in the test bottle works well. This generates enough oxygen to displace the air from the bottle without adding too much liquid volume. The bleach must be added gradually in small portions (1–2 tsp or 5–10 mL) to control the bubbling that occurs. A complete discussion of the chemistry involved, experimental procedures, and notes for the successful reproduction of this reaction as a Tested Demonstration is presented in this issue and the references cited therein *(1)*.

Baking soda ($NaHCO_3$) and vinegar (5% CH_3CO_2H) are used to generate carbon dioxide according to the equation:

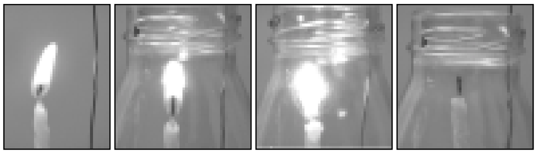
$$NaHCO_3(aq) + CH_3CO_2H(aq) \rightarrow CO_2(g) + H_2O(l) + CH_3CO_2Na(aq)$$

Integrating the Activity into Your Curriculum

This Activity can be used to explore the chemistry of oxygen and combustion. It can also be used in a discussion of redox chemistry or of reaction kinetics, and in particular the effect of a reactant concentration (oxygen) on the apparent rate of a reaction (combustion). The latter may be observed when combustion in oxygen gas (100% oxygen) is compared to combustion in air (21% oxygen).

About the Activity

Oxygen and carbon dioxide gases are generated in glass bottles. The combustion of wood and wax in these gases is observed and compared to the results of burning the same materials in air and bottles of exhaled breath. Combustion is vigorously accelerated in oxygen gas compared to combustion in air and exhaled breath. Exhaled breath supports combustion just as well as air, because the percentage of oxygen in exhaled breath is not materially different from that of air. Carbon dioxide gas does not support combustion. The materials are extinguished when placed in carbon dioxide gas, which is why carbon dioxide is used as a fire fighting agent.



photos by J. J. Jacobsen, A. Tranow, and N. S. Gettys

Left to right, a lit birthday candle supported by a wire is placed in a bottle containing air, in a bottle containing oxygen, and in a bottle containing carbon dioxide.

The shape and size of the bottle opening are important. Clear glass juice and salad dressing bottles of 12–16 fluid oz capacity with an opening of 3–4 cm work well, as do canning jars. The instructor may wish to demonstrate the combustion of steel wool in oxygen to the class *(1)*. After the Activity, pour the mixtures in the oxygen and carbon dioxide bottles down the drain with a large volume of water. Rinse the bottles with water and discard in a recycling bin.

Instructors should be familiar with the cautions printed in the Student Activity (page 1160B); more information is available in the accompanying article *(1)*. Remind students of the importance of following the cautions. A fire extinguisher should be available. Students should not combine bleach with any other chemicals other than exactly according to the Activity procedures. Other combinations can result in the formation of hazardous by-products.

Answers to Questions

1. Pure oxygen supports combustion better than air because air is 80% nitrogen, which does not support combustion. Combustion generally cannot be sustained when oxygen concentrations fall below 10%.
2. Oxygen is used to increase the amount of oxygen that may be absorbed by patients with impaired lung function. The air in the vicinity where oxygen is used may contain significantly more than 20% oxygen. A lit cigarette may burst into a shower of burning fragments under these circumstances.
3. Carbon dioxide gas is unable to support the combustion of most substances.
4. The oxygen in these compounds has already formed extremely stable bonds to other elements. Breaking these bonds to support combustion requires more energy than can be realized from the combustion reaction.
5. We do not absorb all of the oxygen in each breath, nor do we exhale only carbon dioxide and nitrogen. Exhaled air still contains most of its original oxygen content, and generally contains at most only 5% carbon dioxide.

References, Additional Related Activities, and Demonstrations

1. Wright, Stephen W. A Method for Generating Oxygen from Consumer Chemicals. *J. Chem. Educ.* 2003, *80,* 1158–1160.

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You have probably heard the saying "Where there's smoke there's fire". Can you create a similar saying about a chemical that must be present for a fire (combustion reaction) to take place? Combustion is the oldest chemical reaction used by humans. We burn oil, natural gas, coal, wood, and other materials for many purposes. In this Activity you will prepare oxygen and carbon dioxide gases from household chemicals and compare the combustion of different substances in air, oxygen, exhaled breath, and carbon dioxide in order to determine what gas or gases support combustion.

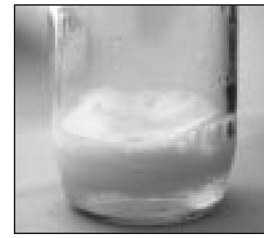

photo by J. J. Jacobsen, A. Trantow, and N. S. Gettys

The reaction between hydrogen peroxide and bleach to produce oxygen is vigorous.

Try This

You will need: 3% hydrogen peroxide; household chlorine laundry bleach (6%); white vinegar (5%); baking soda; plastic measuring spoons or graduated cylinders; 12-oz–16-oz clear glass bottles or jars; cardboard or wood squares to cover the mouths of the bottles; toothpicks; birthday candles; matches; and bare 16-gauge copper wire, tongs, or long forceps.

Be Safe! Because fire is used, special caution is required. SAFETY GOGGLES MUST BE WORN when handling these chemicals and when carrying out the combustion reactions! Experiments should be carried out over a noncombustible surface such as stone, metal, or concrete. ONLY GLASS BOTTLES should be used. UNDER NO CIRCUMSTANCES should plastic bottles be used. Glass bottles may be hot after the experiments and should be handled with care. Chlorine bleach is highly alkaline, poisonous, and can cause serious chemical burns. Do not use the same measuring implements for chlorine bleach and hydrogen peroxide. The oxygen gas generated MUST NOT be inhaled; it may be contaminated with residues of chlorine bleach.

__1. **Combustion in Oxygen:** Place 4 tablespoons (60 mL) of 3% hydrogen peroxide in a clean, empty 12-oz (360 mL) glass bottle [for a 16-oz (480 mL) bottle use 5 tablespoons (75 mL)].

__2. Add 7 teaspoons (35 mL) of household laundry bleach (6%), in portions of 1–2 teaspoons (5–10 mL) each [for a 16-oz (480 mL) bottle use 10 teaspoons (50 mL)]. The mixture will bubble vigorously upon each addition of bleach.

__3. Swirl the bottle to complete the evolution of oxygen, then cover the bottle opening immediately with a cardboard or wood square to prevent the oxygen from escaping. Do not close the bottle tightly, for example with the original bottle cap, a cork, or a rubber stopper! Pressure buildup might shatter the bottle.

__4. Hold a wooden toothpick with long forceps (25 cm or longer), tongs, or a length of bare copper wire. Do not use tape as most tapes are combustible. Light the toothpick and blow the flame out after a glowing ember has formed. The ember must continue to glow red after the flame is blown out.

__5. Uncover the oxygen bottle and quickly lower the toothpick into the bottle, holding it at arm's length. The end with the glowing ember should go into the bottle first. Record your observations.

__6. Repeat Steps 1–5 starting with a clean bottle and substituting a lit birthday candle (don't blow out the candle) for the toothpick.

__7. **Combustion in Carbon Dioxide:** Place 2 tablespoons (30 mL) baking soda in a clean bottle. Add 4 tablespoons (60 mL) white vinegar (5%). Swirl the bottle to complete the evolution of carbon dioxide, then immediately cover the bottle opening with a square of cardboard or wood. Prepare a second bottle of carbon dioxide in the same way. Repeat Steps 4–6 using a glowing toothpick in one bottle and lit birthday candle in the other.

__8. **Combustion with Exhaled Breath:** Take a deep breath and blow it into a clean bottle. Do this four more times, then quickly cover the bottle opening with a cardboard or wood square. Prepare a second bottle of exhaled breath in the same way. Repeat Steps 4–6 using a glowing toothpick in one bottle and a lit birthday candle in the other.

__9. **Combustion in Air:** Repeat Steps 4–6 with two bottles that contain room air.

Questions

1. Which supports combustion better, pure oxygen, or air? Why?
2. Why is oxygen used in hospitals? What might happen if a lit cigarette came near a source of oxygen?
3. What happened when you used carbon dioxide (CO_2) in place of oxygen?
4. Water, carbon dioxide, and sand all contain oxygen. Why can they be used to put out fires?
5. We consume oxygen and expel carbon dioxide as we breathe. Why didn't the fire go out in the jar of exhaled air?

Information from the World Wide Web *(accessed July 2003)*

1. Oxygen. *http://www.webelements.com* (Click on oxygen on the periodic table.)
2. Oxygen in the Atmosphere. *http://www.sciam.com/article.cfm?articleID=000C1FD9-3C36-1C75-9B81809EC588EF21&pageNumber=1&catID=4*; *http://www.sciam.com/askexpert_question.cfm?articleID=000E9FDF-CBC1-1C71-9EB7809EC588F2D7&catID=3*
3. Fire Prevention Week. *http://www.nfpa.org/FPW/index.asp*
4. Fire science. *http://science.howstuffworks.com/fire.htm*; *http://science.howstuffworks.com/fire-extinguisher.htm*