

HOW DO WE AFFECT THE QUALITY OF OUR ATMOSPHERE

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Introduction

We are surrounded by a sea of air. Although the air is of a uniform composition throughout the planet, it does vary locally due to emissions from people, plants, natural disasters, automotive vehicles, and industrial emissions.

In this set of activities, we will look at some constituents of the air and some of the effects of our society on the atmosphere.

Safety

In these activities you will be working with flames, heat, laboratory chemicals, and dilute acids. It is important that you take the proper safety precautions in the laboratory.

Wear safety goggles at all times in the laboratory.

Some laboratory chemicals may be corrosive to the skin. Although most of the materials used in this experiment are considered to be safe in the concentrations used, we will assume that all laboratory chemicals are hazardous and will avoid skin contact. In the event of skin contact, wash the chemical from your skin with water and, if necessary, seek qualified medical assistance. Also, it is good practice to wash your hands when leaving the laboratory.

Hot apparatus looks like cold apparatus. If you heat anything, make sure you use the proper tongs, or clamps to handle the hot apparatus. Give all apparatus adequate time to cool before handling it.

If for any reason you are not sure how to proceed with an experiment or what to do if you have a spill or an accident, call your instructor immediately. Your instructor is present to assist you with any difficulties.

Disposal

Most materials used in this experiment can be disposed of down the drain. You will be advised of any materials that need special disposal methods.

GASES

The composition of dry air in the atmosphere is

Nitrogen	78.1%
Oxygen	20.9%
Argon	0.9%
Carbon dioxide	0.03%
Other gases: neon, helium, methane, krypton, hydrogen, oxides of nitrogen, and xenon	0.07%

Nitrogen, the major component of the air, is a colorless and tasteless gas. It is relatively inert in chemical reactions. Since the laboratory preparation of nitrogen involves an unstable chemical reaction, it will not be performed in these activities.

Oxygen, the second major constituent of the air is a very pale blue in color which is only apparent in the liquid state, but also does contribute to the blue we observe in the daytime sky. Oxygen has no odor. Oxygen is necessary for life as we know it. Oxygen does not burn, but it does support combustion.

Preparation of Oxygen

Oxygen can be prepared by the decomposition of hydrogen peroxide, H_2O_2 , to form water, H_2O , and oxygen gas, O_2 . This process normally takes place over a long period of time. To speed up the reaction in the laboratory, we will add a compound, manganese dioxide, MnO_2 , to the hydrogen peroxide. The manganese dioxide is a *catalyst*, that is, it makes the decomposition of the hydrogen peroxide occur in a very short amount of time.

Safety Note: The 6% hydrogen peroxide solution can cause minor burns to the skin. In the event of skin contact, rinse the affected area with water.

Materials needed:

- 125 mL Erlenmeyer flask
- wood splint
- candle, alcohol lamp, or Bunsen burner
- hydrogen peroxide, H_2O_2 , 6% solution
- manganese dioxide or manganese chips (can substitute active dry yeast)

Procedure

Obtain a 125 mL Erlenmeyer flask.

Add 50 mL of 6% hydrogen peroxide to the flask.

Add 1 g (approximately 1/8 tsp.) of manganese dioxide to the flask.

It will take approximately 1 to 3 minutes to generate sufficient oxygen to allow you to test for its presence in the flask.

Test for the presence of oxygen

Obtain a wood splint. Light the end of the wood splint and let it burn for a few seconds then gently blow it out. The end of the wood splint should be glowing, but not burning.

Insert the glowing wood splint into the flask containing the oxygen gas. What happens?

Disposal

Manganese chips can be reused. Rinse the chips with water, blot them dry and place them in the container provided in the laboratory.

Manganese dioxide powder and spent hydrogen peroxide solution should be put in the appropriate waste bottle.

Active dry yeast and spent hydrogen peroxide solution should be poured down the drain with running water.

Hydrogen is a minor constituent of the air. It is important in that it is a major constituent of water and is the fuel that allows our sun (and all the stars in the night sky) to burn and generate the heat necessary for life on nearby planets. Hydrogen is less dense than air which made it a useful material for blimps and Zeppelins in the early part of this century. Unfortunately, hydrogen is flammable and that property resulted in the explosion and rapid burning of the German airship Hindenburg in Lakehurst, New Jersey, in 1937. All airships currently in operation use helium instead of hydrogen.

Preparation of Hydrogen

Hydrogen can be prepared by the reaction of a metal, such as magnesium, or zinc, with an acid. The rate of hydrogen generation will vary with the amount of the metal and the concentration of the acid used. We will use the reaction of a dilute solution of hydrochloric acid with magnesium metal to generate hydrogen gas, H₂.

Safety Note: The hydrochloric acid used in this experiment is very dilute and should not cause any injury. It is common laboratory practice to treat all laboratory chemicals as though they may be dangerous. In the event of skin contact with hydrochloric acid, put down any apparatus you are working with and go to the nearest sink and wash off the acid with water. Wash well for several minutes.

Materials Needed

- 2 test tubes, 18 x 150 mm
- test tube rack
- hydrochloric acid, 1 M
- magnesium ribbon, 2.5 cm long (1 inch)
- candle, alcohol lamp, or Bunsen burner

Procedure

Obtain two test tubes.

Add 10 mL of 1 M hydrochloric acid to one test tube.

Add one piece of the magnesium ribbon to the test tube and invert the second test tube over the mouth of the first test tube (The test tubes should be positioned mouth to mouth.). The test tube should be held in a vertical position. The bubbles formed in the chemical reaction are hydrogen gas.

Test for the presence of hydrogen

When the magnesium has reacted, remove the top test tube, keeping it *open side down*, and bring the open end near a flame. What happens? Inspect the test tube. What do you observe?

Disposal

The reacted acid solution should be put in the appropriate waste bottle.

Carbon dioxide makes up about 0.03% of the air, but is very important since it is one of the raw materials in the process of photosynthesis, where a plant manufactures its food and produces oxygen as a by-product of the reaction. Without this reaction to replenish the oxygen in the atmosphere, life on Earth, as we know it, would not be possible.

Preparation of Carbon Dioxide

Carbon dioxide can be prepared by the reaction of an acid on a carbonate. We will use the reaction of a dilute solution of hydrochloric acid, HCl, on sodium bicarbonate, NaHCO₃, to generate carbon dioxide gas, CO₂.

Safety Note: The hydrochloric acid used in this experiment is very dilute and should not cause any injury. It is common laboratory practice to treat all laboratory chemicals as though they may be dangerous. In the event of skin contact with hydrochloric acid, put down any apparatus you are working with and go to the nearest sink and wash off the acid with water. Wash well for several minutes.

Materials needed

600 mL beaker
sodium bicarbonate (baking soda), NaHCO₃
hydrochloric acid, HCl, 1 M
wood splint
candle

Procedure

Obtain a 600 mL beaker.

Add 15 g (approximately 1 Tbs.) of sodium bicarbonate to the beaker.

Add 10 mL of 1 M hydrochloric acid to the beaker. What do you observe?

Test for the presence of carbon dioxide

Light a wood splint. Insert the burning wood splint into the beaker of carbon dioxide, but do not touch the chemicals on the bottom or the beaker. What happens?

Light a candle.

Take the beaker of carbon dioxide gas and hold it slightly above the candle flame.

Pour the carbon dioxide gas over the candle flame. Take care NOT to pour any of the liquid in the beaker over the flame. What happens? What does this tell you about one of the properties of carbon dioxide? (NOTE: If you do not have sufficient carbon dioxide in the beaker, add an additional 10 mL of hydrochloric acid to the beaker and repeat this procedure.)

Disposal

The sodium bicarbonate-hydrochloric acid solution can be poured down the drain with running water.

Simulating the Greenhouse Effect

Carbon dioxide, released into the atmosphere by industries burning fossil fuels (petroleum, natural gas, and coal) contributes to a process called the **greenhouse effect**. The greenhouse effect is similar to the process that occurs when growing plants in a greenhouse. The glass walls and roof of the greenhouse allow the sun's heat to pass through and traps it in the building making temperatures warmer than the surrounding environment. In a similar manner, the gases in the atmosphere allow the sun's rays to reach the Earth and traps them warming the Earth's surface. Some of the trapped heat does escape into space to produce a cooling effect on the Earth. The balance of the warming and cooling gives us the perfect climate conditions for life as we know it. When there is a large amount carbon dioxide released into the atmosphere, it, along with other gases, increases the amount of heat trapped and reduces the amount that escapes causing a warming of the Earth. That warming, called **global warming** will result in warmer temperatures, melting of the polar ice caps, changes in the water cycle, and severe weather changes.

Materials needed

- Candle
- 400 mL beaker
- beaker tongs

Procedure

Light a candle.

Obtain a 400 mL beaker.

Hold the 400 mL beaker upside down over the candle so that the flame is positioned about *half-way inside* the beaker. Burning candle wax produces carbon dioxide, water vapor, and some soot (particles of carbon). Observe and record the changes that take place.

A Cloud in a Bottle

Water vapor is another component of the air. The amount of water vapor in the air varies and is expressed in the terms of relative humidity. That is, the amount of water in the air at the current temperature and air pressure divided by the maximum amount of water vapor the air can hold. Some of the water vapor collects in the air in the form of clouds.

A cloud can be formed when water vapor encounters particulate material in the air at the correct temperature. Small droplets of water form which collect together in the form of a cloud.

Materials needed

- 2-Liter bottle with cap
- wood splint (or wood match)
- water

Procedure

Obtain a 2-Liter soft drink bottle with a cap.

Add some room temperature water to the bottle. Cap the bottle and shake well for at least 10 seconds. Open the bottle and pour out the water. Replace the cap on the bottle. There should be a small amount of water remaining in the bottom of the bottle.

Light a wood splint or a wood match. Allow it to burn for a few seconds. Open the bottle and drop in the burning splint, then *cap the bottle tightly*. The burning splint should go out leaving some white smoke in the bottle.

Squeeze the bottle hard. The inside of the bottle should be clear.

Release the pressure on the bottle.

Repeat this squeezing and releasing procedure. What do you observe?

Acids, Bases, and pH

This investigation will use red cabbage paper to test acids and bases and determine their relative pH values. pH is a measure of the relative strength of an acid or base. The pH scale goes from 1, chemically strong acid, to 14, chemically strong base, with 7 being neutral. As pH values get closer to 7, the acid or base is considered to be a chemically weak acid or chemically weak base.

Materials needed

Red cabbage paper. The paper should be available in the laboratory for use in this experiment. The method of preparing the red cabbage paper is given below.

Buffer solutions. Approximately 5 mL of pH 1, 2, 4, 6, 7, 8, 10, 12, 14 in separate, labeled plastic cups (Buffers are made from buffer capsules, available from science supply companies. Note: pH 1 is 0.1 M HCl, pH 14 is 0.1 M NaOH)

Plastic cups, 3 ounce (90 mL)

Plastic stirring rods such as coffee stirrers which are thin straws.

Assorted household materials in liquid form or solutions placed in separate, labeled plastic cups. These consist of materials such as toothpaste, laundry detergent, shampoo, lightly colored soft drinks, soap, baking soda, lemon juice, vitamin C, mouthwash, and any other household materials available. For solids or pastes, add a small amount of distilled water to make a solution.

Red Cabbage Paper is made from red cabbage juice.

To prepare red cabbage paper at home, place some red cabbage in a blender with ethyl rubbing alcohol (70% ethyl alcohol in water). Blend until smooth. Strain the liquid through several layers of cheesecloth.

Safety Note: Ethyl alcohol is flammable. Keep it away from flames. Do not fill the blender more than one-half full to avoid splashing any alcohol from the blender. Sparks from the blender motor can ignite any spilled or splashed alcohol.

Obtain filter paper circles or coffee filter circles. Dip in the red cabbage juice. Lay out in a single layer on clean table tops to dry. Store in a Ziploc type bag in a cool dark place. Will keep for 6 months or longer with no odor or spoilage.

In this experiment, we will use buffer solutions that are special solutions having a known pH. We will use pH solutions of 1, 2, 4, 6, 7, 8, 10, 12, 14.

Which substances you tested are acids?

Which substances you tested are bases?

What does “pH balanced” mean in some household products?

Acid Rain (Instructor Demonstration)

The emissions of carbon dioxide, oxides of nitrogen, and oxides of sulfur, from burning fossil fuels by industry and automobiles will mix with the water in the air producing weak acids. When it rains, the weak acids affect our environment by reacting with many different materials which make up our buildings, statues, etc. and changing the acidity (pH) of the soil and streams.

Simulating Acid Rain

The small aquarium is set up to simulate part of our environment. At one end of the aquarium is a small “pond” consisting of distilled or deionized water. At the other end is a candle which is sprinkled with a small amount of powdered sulfur and a small container which contains a penny. When the candle burns, it generates carbon dioxide and some sulfur dioxide, similar to a large factory that may be burning fossil fuels. The penny is reacted with concentrated nitric acid to produce oxides of nitrogen similar to those produced by automobile emissions. The aquarium is covered with an aluminum foil baking pan that has a number of small holes in it.

The pH of the water in the pond is measured. The pH value is _____

The candle is lit and nitric acid is placed on the penny. What do you observe?

How does the atmosphere in the aquarium change? What you are observing is smog.

Water is introduced into the aluminum foil baking pan. As it drips through the holes, it simulates rain. How does the rain affect the atmosphere inside the aquarium?

The pH of the water in the pond is measured again. The pH value is _____

A piece of limestone is placed into the pond. Do you observe any changes.

The pH of the water in the pond is measured a third time. The pH value is _____

Summarize what you discovered about acid rain.

Assessing the Effect of Acid Rain on Our Environment

This investigation consider the effect of acid rain on some common rocks and minerals.

Safety Note: The hydrochloric acid used in this experiment is very dilute and should not cause any injury. It is common laboratory practice to treat all laboratory chemicals as though they may be dangerous. In the event of skin contact with hydrochloric acid, put down any apparatus you are working with and go to the nearest sink and wash off the acid with water. Wash well for several minutes.

Materials needed

- Mineral samples (labeled)
- Hydrochloric acid, HCl, 1.0 M
- Dropper
- Dishes to hold mineral samples (labeled)

Procedure

Several mineral samples will be available in the laboratory.

List the name of the mineral tested in the table below.

Test each mineral sample for reaction to acid by placing ONE DROP of hydrochloric acid on the mineral. Observe any reaction that takes place and note that in the reaction column next to the mineral name. If there is no reaction observed, write NR in the reaction column.

Mineral

Reaction with Acid

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Crush a Can With Air Pressure

Air pressure, at sea level, is measured at 15 pounds per square inch of surface area, or, expressed in barometric pressure of 760 mm Hg (millimeters of mercury). Normally, we don't feel that pressure since we have lived with it all our lives. Changes in pressure are more apparent when we change altitudes rapidly and can feel the pressure change as a popping in our ears or at the bottom of a swimming pool where the pressure of the water is added to the pressure of the air.

Safety Note: The hot plate and the metal cans will be very hot. Do not touch the surface of the hot plate. Do not touch the metal cans. Use a pair of beaker tongs to handle the hot metal cans. After using the hot plate, turn it off and allow it to cool for 15 minutes before trying to handle it.

Materials needed

- Aluminum beverage cans
- Beaker tongs
- Beaker, 600 mL or 1000 mL (Substitute a plastic container, such as a shoe box.)
- Hot plate

Procedure

Obtain an empty, washed, aluminum soft drink can.

Add about 10 mL of water to the can and place the can on a hot plate. Set the heat on high.

Fill the 600 or 1000 mL beaker about $\frac{3}{4}$ with room temperature water. Place the beaker near the hot plate.

When the water in the can boils, pick up the can with a pair of beaker tongs, move it above the container of water, *turn it upside down* so that the opening is on the bottom and immerse it in the water. What happens?

Can you explain why the change occurred?

Simulated Sunset (Instructor Demonstration)

You are probably aware of the red and orange colors that occur when the sun sets in the evening and also when the sun rises in the morning. The colors are a result of the sunlight being scattered by the molecules of gas and the particulate matter in the air. The scattering is most prominent in the early morning or late afternoon because the light from the sun has a longer path through the atmosphere to your viewing position than it does during the day when it is higher in the sky. That longer path results in more scattering of the light where the longer wavelengths of light (the red light) penetrate the atmosphere better and the blues, greens, and yellows penetrate less.

Materials needed

- Beaker, 2000 mL
- Sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, crystal
- Hydrochloric acid, HCl, 1M
- Sheet of heavy paper with a 5-6 cm diameter circular hole cut in the center
- Water
- Stirring rod
- Overhead projector with screen

Procedure

Place 1500 mL of water in the 2000 mL beaker. Add 10 g sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$. Stir to dissolve.

Place the sheet of heavy paper on an overhead projector.

Place the beaker on the paper, centered over the round hole.

Add 50 mL of 1 M hydrochloric acid to the beaker. Stir to dissolve.

Dim the room lights.

In a short while, the solution in the beaker starts to become cloudy and the light passing through the beaker becomes visible. Observe how the color of the light, scattered in the solution, changes as the solution becomes cloudy. Record your observations.

Observe how the color of the light on the screen changes as the solution becomes cloudy. Record your observations.

Explanation

The large beaker on the overhead projector contains a solution of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, that is being reacted with dilute hydrochloric acid, HCl . One product of the reaction is small particles of sulfur which form suspended in the solution. As the particles start to form they become visible in the light beam as it passes through the solution. The visible beam showing the particles is known as the Tyndall effect (named for the scientist, John Tyndall, who first described the effect) As the number of particles increase, they start to scatter the light, similar to the same effect that takes place when the sun rises or sets.

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TEACHER NOTES

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Assessing the Effect of Acid Rain on Our Environment

This investigation consider the effect of acid rain on some common rocks and minerals.

Mineral samples that can be used:

- Limestone
- Marble
- Granite
- Sandstone
- Pumice
- Basalt
- Garnet schist
- Mica schist
- Slate
- Lava
- Obsidian
- Quartz
- Calcite
- Conglomerate

Place mineral samples in petri dishes. Label the petri dish on the bottom side so that the name of the mineral can be read, but the acid will not affect the label.

Caution the students to use ONLY ONE DROP of the acid.

Simulated Sunset

Materials Needed

- Beaker, 2000 mL preferred (can use 1000 mL size)
- Sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$
- Hydrochloric acid, HCl, 1.0 M
- Paper to cover overhead projector with 2-inch diameter hole in center
- Water

Set-up

Place paper on overhead projector so that only a beam of light can be seen.

Place beaker with approximately 1500 mL of water on the overhead projector. Center beaker over hole in paper.

Add approximately 10 g sodium thiosulfate to beaker for each 1000 to 1500 mL of water. Stir to dissolve.

Add approximately 50 mL of 1.0 M HCl solution to the beaker. Note: The rate of the reaction can be varied by changing the amount of HCl solution used. (A rate of about 2 to 3 minutes for the reaction to take place is recommended.)