

- Illustrated Script -

**The Chemistry of
the Earth's Atmosphere and Beyond:
A Hands-on Program**

An Educational Demonstration Package

**Prepared by the
Cleveland Section
of the
American Chemical Society**

National Chemistry Week 2003

Overview

From balloons to rockets, from the earth to the moon... chemistry gets us there and back again! Come celebrate National Chemistry Week by joining in an hour of uplifting hands-on experiments that show how chemistry provides the power! While conducting hands-on experiments, students will learn about the components of air, how much air surrounds us, Bernoulli's principle and air movement, solubility of gases in liquid, how to detect carbon dioxide, and the effects of air pressure. We will discuss these in terms of how we have learned to travel through the atmosphere and into space, and we'll even see how to use pressure to launch a rocket.

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Acknowledgments

The National Chemistry Week (NCW) programs of the Cleveland Section ACS began in 1994 with an idea to put together a scripted program that could be performed at any local school or library. This idea has expanded to become the centerpiece of Cleveland Section's NCW activities, which has received national recognition from the American Chemical Society. In 2003, the Cleveland Section volunteers will perform over sixty demonstrations at libraries, schools, and other public sites. Continuing our relationship started two years ago, the Cleveland Section will also be providing training and materials for Cleveland-area teachers, at the Cleveland Regional Council of Science Teachers' Fall Conference, so that they can conduct additional programs in their own classrooms.

This library/school program and other NCW events are the result of the hard work of many dedicated and talented volunteers. It all starts with our local section NCW Planning Committee. The Committee develops a theme for the program; recommends, tests, and reviews activities & experiments; writes a script; collects supplies and materials; prepares the kits; recruits sponsors and volunteers; contacts libraries and schools; and schedules shows. This Committee, as well as the rest of the Section's NCW activities, were overseen by the Cleveland Section's NCW coordinators for 2003, Paula Fox, Kat Wollyung and Betty Dabrowski. Committee members include Rich Pachuta, Lois Kuhns, Don Boos, Helen Mayer, Jesse Bernstein, Marcia Schiele, Mark Waner, Shermila Singham, David Ball, Bob Fowler, Kelly Dobos, Liz Herbell, and Reiko Simmons. Additional credit and thanks is given to all of the many GAK (Grand Assembly of Kits) Day volunteers, including the John Carroll University ACS Student Affiliates, who gave up a Saturday in September to help count, measure, and assemble all of the necessary materials for our demonstration kits.

Our NCW efforts reach many children year because of various sponsors who have donated money, materials, and/or services to the Cleveland Section specifically for National Chemistry Week. We are especially grateful to Stouffer/Nestle Foods, the Dollar Tree Store in Middleburg Heights, Buehler's in Wadsworth, the NASA Glenn Research Center, John Carroll University, the Cuyahoga County Public Libraries, Chardon High School Honor Society students, and other anonymous sponsors for their numerous contributions and support.

Last and most important, we thank all the volunteers who donate their time and expertise. Without the dozens of dedicated chemical professionals to lead these activities, there would be no Cleveland Section NCW program.

How Experiment Write-ups are Organized

The materials and set-up of the demonstrations are located in the introduction section of this packet. Then, each experiment write-up is presented as follows:

- * Background Information for Demonstrators
- * Demonstration Instructions
- * Experiment Conclusions
- * Additional Information If Needed

Presentation Overview

This section describes the basic presentation technique used during the demonstrations. This is a guideline only as the technique may vary for some experiments. Make sure you follow the instructions given in each experiment.

1. Introduce experiment.
2. Do your demonstration piece.

Note: Most experiments require you to perform the experiment to show the students what to do on their own.

3. Have the students do their experiment.

Note: For some experiments your demonstration and the student's hands-on work are nearly simultaneous. You are leading them as they perform the experiment.

4. Some experiments will be done by all students. For others, there will be one experiment that will be shared by all students at the table. In a few cases, only the demonstrator will perform the experiment. You are encouraged to get student helpers for the demonstrator-only experiments.

MAKE SURE TO FOLLOW ALL DIRECTIONS IN EXPERIMENTS

Some experiments may have special safety concerns due to the materials being used. Any safety concerns are listed in the section for that experiment. Any MSDS's necessary would typically be found in the Appendix, however, there are none necessary for this year's program.

For information about the American Chemical Society's NCW safety guidelines, visit www.acs.org/portal/Chemistry?PID=acsdisplay.html&DOC=new%5Csafetyguidelines.html

Demonstration Check-Off List

The next few pages list suggested activities to complete for the program.

Activities To Do Before the Day of the Demonstration	✓ When Complete
Read through this packet to familiarize yourself with the experiments	<input type="checkbox"/>
Contact xxx or xxx with any questions.	<input type="checkbox"/>
Collect the materials you need to bring with you to the demonstration. The materials list is on page 7.	<input type="checkbox"/>
Contact the children's librarian: <ul style="list-style-type: none"> * Ask the room to be arranged with 6 tables around a front table * Ask to have 5 chairs around each of the 6 tables * Ask for all the tables to be covered with newspapers and for extra paper towels for each table. * Ask about availability of demonstration materials from list of page 7 (ex. paper towels, newspaper) * Make sure that the room is available before and after the program for set up and clean up. 	<input type="checkbox"/>
Activity To Do AT LEAST ONE DAY BEFORE the Demonstration	✓ When Complete
There are no specific experimental preparations to do before coming to this year's program.	<input type="checkbox"/>

Continued next page

Demonstrator's Guide

Activities To Do When You Get To The Library	✓ When Complete
Arrive approx. 1 hour before demo time to allow for set up	<input type="checkbox"/>
Introduce yourself to the children's librarian	<input type="checkbox"/>
Ask the librarian how many students are pre-registered	<input type="checkbox"/>
Confirm that the tables and chairs are set up properly	<input type="checkbox"/>
Confirm that all tables are covered in newspaper and have paper towels	<input type="checkbox"/>
Obtain those supplies from list on page 7 if provided by library	<input type="checkbox"/>
Complete Demonstration Set-Up for all demonstrations: (see "Activities to Do On-Site Prior to Demonstration" on page 10)	<input type="checkbox"/>
<i>Note: This set-up is estimated to take 30-45 minutes.</i>	
Set out the literature (Experiments To Do at Home, Book List, ChemMatters magazines, and Celebrating Chemistry newspapers)	<input type="checkbox"/>

Activities To Do During The Demonstration	Timing
Welcome the students and parents as they enter the room.	-
Hand out goggles and help adjust to the correct fit (if necessary).	-
Assess number of students per table and adjust to 3 - 5 per table. Record the number of students and adults.	-

Continued next page

Demonstrator's Guide

Activities To Do During The Demonstration (Continued)	Timing
Complete the Opening Session Introduction	4 min.
Perform demonstrations	
* Experiment 1: What is Air? ...and... What are the Components of Air?	3 min.
* Experiment 2: PPM Measurement of Trace Components of Air.	5 min.
* Experiment 3: Air Pressure	5 min.
* Experiment 4: Proof of Air Movement – Goldenrod paper	3 min.
* Experiment 5: Solubility of Gases – Soda Fountain	5 min.
* Experiment 6: Air Flow and Bernoulli's Principle	10 min.
* Experiment 7: Alka-Seltzer® Rockets	5 min.
* Experiment 8: Marshmallow Syringes	10 min.
* Experiment 9: CO2 Detection	5 min.
Complete the Closing Session information, collect goggles, hand out literature	5 min.
	<i>Total Time: 60 min.</i>

Activities To Do Immediately After The Demonstration	✓ When Complete
Clean up as indicated in the Clean Up section (page 36)	<input type="checkbox"/>
Record the number of adult and student participants on the feedback sheet	<input type="checkbox"/>
Give any leftover literature to the librarian (<i>library kits only</i>)	<input type="checkbox"/>
Place the feedback form and other supplies into the envelope(s) provided and give it and the box of goggles to the librarian so that they can be returned to the branch at Solon by interlibrary mail. (<i>library kits only</i>)	<input type="checkbox"/>

Activities To Do Once You Get Home	✓ When Complete
Leave a message for xxx with attendance information	<input type="checkbox"/>

Supplies Required for Demonstration

Items for Demonstrator to Provide (marked w/ * in individual experiments below)

- 1-gallon jug or small bucket for liquid waste collection (Do NOT plan to use the gallon jugs from the air pressure demonstration since you will need to be collecting waste during some of the demos)
- 1 large garbage bag for solid waste collection
- 1 roll paper towels, if none at site
- Newspaper for covering tables, if none at site
- Scissors
- Water (if none available at library) – about 1 quart, plus enough to fill the gallon jugs
- Sharpie-type pen (for drawing smiley faces on marshmallows)

Notice: If you will be performing multiple demonstrations on the same day, you will need to sanitize the goggles between demonstrations. You will also need:

- Small quantity of household bleach
- Wash bin or bucket
- Rags, old towels, or cotton paper towels for drying (soft so as not to scratch the goggles)

Items Provided in Each Demonstration Kit:

General:

- 1 box to hold kit contents
- 30 copies *Celebrating Chemistry newspapers*
- 30 copies each of “Book List”
- 30 copies each of “Experiments To Do at Home”
- 10 copies of *ChemMatters* magazine (*library kits only*)
- 1 demo feedback form and return envelopes (addressed to Solon) (*library kits only*)
- 1 box of goggles (30 child & 2 adult size, addressed to Solon Library) (*library kits only*)

Experiment 1: What is Air? ...and... What are the Components of Air?

- 31 “Components of Air” paper strips – see appendix for example
- 1 balloon
- 1 empty 9-oz. clear plastic cup

Experiment 2: PPM Measurement of Trace Components of Air

- 7 egg cartons
- 7 (clear or colored) 9-oz. plastic cups marked “water”
- 14 pipets or eyedroppers
- 1 sealed pipet containing a 10% food coloring solution (one part in ten)

Experiment 3: Air Pressure

- 2 empty gallon jugs
- Rope or string (for tying the set-up together)
- A one-inch square of wood with a hole drilled in center

Experiment 4: Proof of Air Movement – Goldenrod paper

- 14 two-oz. portion cups
- 14 small pieces of goldenrod paper
- 1 vial marked ‘ammonia’
(containing ~35 mL of household ammonia diluted 1:1 with water)
- 1 cotton swab

Experiment 5: Solubility of Gases – Soda Fountain

- 1 12 to 16-oz. bottle of lemon-lime soda
- 1 small tray with enough volume to contain the entire bottle of soda
- 2 mixed fruit Mentos[®] candies

Experiment 6: Air Flow and Bernoulli's Principle

- 7 long thin bags (additional bags may be included in your kit)
- 31 small wooden spools
- 31 paper circles with metal clasps through the center

Experiment 7: Alka-Seltzer[®] Rockets

- 7 empty clear film canisters (decorated with pom-pom “pilot”)
- 2 Alka-Seltzer[®] tablets in sealed package
- 7 3-oz. paper cups
- 1 small tray with sides (similar to tray provided in Experiment 5)

Experiment 8: Marshmallow Syringes

7 plastic syringes about 30 ml in size with a cap (no needles)

31-40 mini-marshmallows

**Optional—Sharpies pens for drawing smiley faces (provided by demonstrator)*

Experiment 9: CO₂ Detection

14 9-oz. clear cups (7 marked "H₂O" and 7 marked "CO₂") (one with 'fill line' mark)

31 drinking straws

2 beral pipets containing bromothymol blue or universal indicator

Activities to Do On-site Prior to Demonstration

General:

✧ Refer to page 5 for items to verify room setup (6 student tables with 5 chairs each, one demonstrator table, all covered with newspaper, each with paper towels, etc. & obtain any supplies requested from librarian)

Experiment 1: What is Air? ... and... What are the Components of Air?

- ✧ Place 5 'Components of Air' paper strips on each student table and one on the demonstrator's table.
- ✧ Place the balloon on the demonstrator's table. (You may want to blow it up and empty it a few times so that it is easy to blow up during the demonstration later.)
- ✧ Place the clear empty cup on the demonstrator's table.

Experiment 2: PPM Measurement of Trace Components of Air

- ✧ Fill the clear or colored plastic cups marked "water" about half full with water.
- ✧ Place one egg-carton, two pipets, and one cup of water on each of the seven tables.
- ✧ Place the pipet containing 10% food coloring solution on the demonstrator's table.
- ✧ Locate the scissors you will later use to cut open the pipet during the demonstration.

Experiment 3: Air Pressure

- ✧ Fill the empty one-gallon jugs to the lines indicated (the combined weight of the filled jugs will be 14.7 pounds).
- ✧ If the demonstration apparatus is not assembled, use the string and one-inch square of wood to connect them. (See Appendix for diagram.)
- ✧ Place the apparatus on the demonstrator's table.

Experiment 4: Proof of Air Movement

- ✧ Place 2 empty portion cups and one cotton swab on each of the seven tables.
- ✧ Place two pieces of goldenrod paper at each of the seven tables.
- ✧ Leave the vial marked 'ammonia' on the demonstrator table - Do NOT open the vial.
- ✧ Place one cotton swab at the demonstrator's table.

Experiment 5: Solubility of Gases

- ✧ Place one small tray, the bottle of soda (unopened), and the bag of Mentos candies on the demonstrator's table.

- * Have paper towels handy.

Experiment 6: Air Flow and Bernoulli's Principle

- * Place 5 paper circles with metal clasps and 5 wooden spools at each student table, and one of each at the demonstrator's table.
- * Place all 7 long thin bags on the demonstrator's table. Do NOT distribute bags to student tables at this time.

Experiment 7: Alka-Seltzer[®] Rockets

- * Fill each film canister about $\frac{1}{2}$ full with water. Cap and place one on each of the seven tables.
- * Break each Alka-Seltzer[®] tablet into about 3 – 4 pieces and distribute the pieces evenly among the paper cups.
- * Place one cup containing Alka-Seltzer[®] pieces on each of the seven tables.
- * Locate the second tray and place it on the demonstrator's table.

Experiment 8: Marshmallow Syringes -

- * Place one syringe with cap on each of the students' tables and one on the demonstrator's table.
- * Place 5 marshmallows on each of the students' tables and one on the demonstrator's table.
- * Optional: You may wish to provide a marking pen for each table so that the students can draw a smiley face on the marshmallow before the experiment. Or you can draw the faces yourself as part of your set-up.

Experiment 9: CO₂ Detection

- * Use the cup with the 'fill line' mark to fill all 14 cups with the appropriate amount of water.
- * Place one cup marked "H₂O" and one marked "CO₂" on each table.
- * Place one drinking straw on the demonstrator's table, and 5 straws on each student table.
- * Place the two beral pipets of bromothymol blue or universal indicator on the demonstrator's table.

Opening Discussion

Introductions

Do the following:

- * Introduce yourself as a chemist, and introduce the American Chemical Society as the largest organization in the world devoted to a single profession.
- * Introduce National Chemistry Week - what it is and why we do it. (*Hint: it is a nationwide event put on by volunteers like you to let non-chemists know about chemistry and how it has improved our everyday life.*)

What is Chemistry and Chemicals?

Do the following:

- * Explain that chemistry is the study of everything around them.
- * Ask volunteers to name some chemicals. Then ask more volunteers to name something that isn't a chemical.

Remember: everything around us is a "chemical".

Be very careful in correcting the students. Encourage their participation while explaining that anything they name really is a chemical.

What Do Chemists Do?

- * Ask the participants to tell you what a chemist does, what a chemist looks like.
- * Tell them BRIEFLY and in simple terms what you do as a chemist.

Note: This should last no more than 1 minute. Remember to leave the physical chemistry lecture and the "big" chemistry words at home!

- * Tell them that chemists use their knowledge to answer questions about the world around them. This is very exciting, as they will soon see.

Introduce the Items on the Tables

Do the following:

- * Tell them not to touch anything until told to do so. Remind them never to taste or smell anything, as if they were in a laboratory.

Note: Some of the items in the demonstration are actual food items. Remind students throughout the demonstration not to eat or drink anything!

Introduce Today's Presentation:

The Chemistry of Earth's Atmosphere and Beyond

Tell the students the following:

- * When we hear the word “chemical” in the news, it is often in a story about a ‘bad’ or ‘dangerous’ chemical spill, or how a chemical has been found to be harmful to our health. But this isn’t always the case! Chemistry can be good for us too!
- * Have the students try to name a few helpful ‘chemicals’. [Medicines and vitamins, gasoline and oil for cars, fertilizers, cleansers/detergents.]
- * Tell the students that we will be using the scientific method to guide us in our investigation of the properties of gases in our atmosphere such as air pressure and how they effect air travel. We will make observations, form a hypothesis, use experiments to test our hypothesis, and then evaluate the results of the experiment to accept or reject the hypothesis.

Introduce the Items on the Tables and Distribute Goggles

Do the following:

- * Tell the students that various items have been gathered for them on their table.
- * Tell them not to touch anything until instructed to do so.
- * Most of the items can be found around the house. *Remind them never to taste or smell anything, as if they were in a laboratory!*
- * Tell the students that even though most of our items are relatively harmless toady, we will still be good chemists and take the safety precaution of protecting our eyes.
- * Put on a pair of the adult-sized goggles. If you have an assistant, ask them to do the same.
- * Distribute the goggles (if you haven’t already done so) and help the students put them on. Adjust the straps as necessary.

Experiment 1: What is Air? ..and..What are the Components of Air?

Experiment Purpose & General Methodology

- 〈 The students will be informed of the components of air.
- 〈 This discussion will be with the whole class and should only take a few (3) minutes.

Introduce the Experiment

Tell the students the following:

- * Say: Every day hundreds of thousands of people travel by air across the globe. Occasionally some people get to fly into outer space. How have we achieved these feats? We travel through air on a daily basis, but what do we know about this stuff (wave both of your hands through the air as you say this as if you are stirring up the air around you).
- * Tell the students that throughout our experiments today we will learn about air and its connection to travel.

Perform Experiment with the Students

Do the following:

- * Pick up an empty cup. Ask the students what is in the cup. After some say 'nothing' and you keep asking, get them to say 'air'.
- * Blow up a balloon. Hold it closed with your fingers. Ask the students what is inside the balloon (Air) and what makes it larger now than it was when you picked it up off the table (Pressure).
- * Let the balloon go (being careful where you point it) and allow it to fly away. Ask the students what made the balloon move. (The air pressure inside the balloon was greater than that in the room, so the air came out of the end of the balloon causing it to move in the opposite direction). Point out how powerful a little bit of air can be.
- * Have the students list some components of air. (What do we breathe in, breath out, see, smell, feel) (Oxygen, carbon dioxide, dust, fragrance/flowers, moisture)
- * Have the students look at the list of components of the air. (See appendix) What is the largest component? Nitrogen. Gee and our bodies don't even make use of that component when we breathe!

Additional Information If Needed: Technical Background

- From www.planetary.org, www.astronomy.com, and web sites at the Department of Geology and Geophysics, University of Hawaii, Honolulu HI 96822.
- Why is nitrogen the most common element in the earth's atmosphere? The answer lies mostly in three facts:
 1. Nitrogen is volatile in most of its forms.
 2. It is unreactive with materials that make up the solid earth.
 3. It is very stable in the presence of solar radiation.
- The Earth's atmosphere was formed by planetary degassing, a process in which gases like carbon dioxide, water vapor, sulfur dioxide and nitrogen were released from the interior of the Earth from volcanoes and other processes. Life forms on Earth have modified the composition of the atmosphere since their evolution.

Compared to atomic Oxygen (O), atomic nitrogen (N) is 4 times as abundant in the atmosphere. However, we must also consider the relative abundances of O and N over the entire Earth, where oxygen is about 10,000 times more abundant. Oxygen is a major component of the solid earth, along with Si and elements such as Mg, Ca and Na. Nitrogen is not stable as a part of a crystal lattice, so it is not incorporated into the solid Earth. This is one reason why nitrogen is so enriched in the atmosphere relative to oxygen. The other primary reason is that, unlike oxygen, nitrogen is very stable in the atmosphere and is not involved to a great extent in chemical reactions that occur there. Thus, over geological time, it has built up in the atmosphere to a much greater extent than oxygen.
- Nitrogen is relatively unreactive compared to oxygen. It is one theory that aging is partially due to oxidation on a molecular scale. This is why 'anti-oxidants' are thought to improve our health.
- The atmosphere of Mars is made out of 95% carbon dioxide and only 3% nitrogen. Mercury: atmosphere contains sodium and potassium. Venus: carbon dioxide with clouds of sulfuric acid. Jupiter's atmosphere is composed primarily of hydrogen and helium in nearly the same abundances found in the Sun and other stars; other compounds have also been found, including methane, water, ammonia, acetylene, carbon monoxide and hydrogen cyanide. Uranus is one of the 'gas giants' composed of methane and other hydrocarbon gases.
- We'll learn more about CO₂ (carbon dioxide) later in this program.

Experiment 2: PPM Measurement of Trace Components of Air

Experiment Purpose & General Methodology

- 〈 The students will learn that ‘trace components’ are small amounts of material.
- 〈 This experiment will be done per table and will take approximately 5 minutes to complete.

Introduce the Experiment

Tell the students the following:

- * As we just discussed, most of the air in our atmosphere is made up of nitrogen, but there are many components that are found in VERY small quantities. These are often called ‘trace components’ and sometimes we need very sophisticated equipment to “see” or detect them.
- * The most sophisticated instruments available today can measure particles in water or air to parts per million, or parts per billion, and in some cases even parts per trillion. “Parts per” means one part in some quantity – like one part in one million parts. Many trace components of gases in the atmosphere are measured in parts per million, or ppm.
- * So what do these numbers mean? It’s difficult to picture one million of something in order to know just how small of an amount is ‘one in a million’.
- * Here’s one way to think about it: imagine Jacob’s Field which holds about 40,000 people. If you had no idea where a friend of yours was seated at the stadium, how easily could you pick out that person in the crowd? Being able to see your one friend in Jacob’s Field is picking out one person in forty thousand. Yet we measure concentrations that are one part per million – so now you are looking for that one person in a crowd of a million people or some place 25 times the size of Jacob’s Field!
- * We will do an experiment that shows what happens as you progressively dilute a sample from one part in ten to one part in one hundred, all the way to one part in one million.

Perform Experiment Simultaneously with the Students

Do the following:

- * Have a students locate the cup marked “water”, two pipets, and the egg carton.
- * Ask the children if they can count by powers of 10 (which means you multiply by ten each time) - zero, 10, 100, 1000,



Experiment 2

Demonstrator's Guide

up to one million.

* Show your students the pipet filled with the food coloring solution. Walk around the room and place a few drops of this solution into the first section of the students' egg cartons (try to equally distribute the food coloring among the student cartons and your own).

* Tell the students that you have already diluted your food coloring solution by adding one drop of food coloring for each 9 drops of water that were added. Thus you already have a "one part per ten" solution of the food coloring.

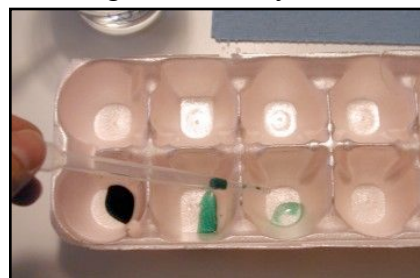


* Inform the students that they will need to keep one pipet for adding water and the second pipet for transferring the colored solutions. Suggest that the students leave the water pipet in the water cup to avoid mixing up the pipets.

* Have a student place exactly 9 drops of water into section #2 of the egg carton using the water pipet. Then have the student use the second pipet to transfer one drop of the solution from section #1 (the One part in Ten solution) into section #2 now containing water. Ask the students what solution they have just made. (One part in 100)



* Repeat this step with sections #3 thru #6 with each student taking a turn. As you create



⊙ #3 1 part in 1,000

⊙ #4 1 part in 10,000

⊙ #5 1 part in 100,000

⊙ #6 1 part in 1 million



* Ask the children in which space do they first observe no visual evidence of the presence of the food coloring. Can you see the color in the last space?

Conclusions

Tell the students the following:

* Ask the students: Since you cannot see any color present in the last space, how do you know there is indeed food coloring present? Can you think of any experiments that might prove that there is food coloring present in each space in the egg carton? (Evaporate the water.)

Additional Information If Needed: Technical Background

- Carbon dioxide is typically present in air at 350 ppm. At levels of 30,000 ppm it becomes hazardous to our health. We'll learn more about this in a later experiment.
- Most people can smell chlorine in water below only 5 ppm and cleaning ammonia at 25 ppm! From www.ufcw.org United Food and Commercial Workers web site.

Experiment 3: Air Pressure - How much air is out there?

Experiment Purpose & General Methodology

- < The students will have a chance to feel the weight of a one square inch column of air.
- < This demonstration is to be done with the entire class and is expected to take 5 minutes.

Introduce the Experiment

Tell the students the following:

- * We live at the bottom of a very large blanket of air we call the atmosphere. It reaches over 560 kilometers (348 miles) from the surface of the Earth, so we are only able to experience what occurs fairly close to the ground. The atmosphere, solar energy, and our planet's magnetic fields support life on Earth. The atmosphere absorbs the energy from the Sun, recycles water and other chemicals, and works with the electrical and magnetic forces to provide a moderate climate. The atmosphere also protects us from high-energy radiation and the frigid vacuum of space.
- * Air is composed of 78% nitrogen and 21% oxygen and other gases as we discussed earlier. Some other planets and moons have different atmospheres such as ammonia or methane.
- * Tell the students that air seems lightweight, and it is. You can jump up and down and wave your hands in the air fairly easily. If we compare air and water, a gallon (3.8 Liters) of air only weighs 0.2 ounces (5.7 grams), while a gallon of water weighs approximately 8 pounds (3.6 kg).
- * On the other hand, when there is a lot of air, it starts to add up and the air can seem heavy. Because there is so much air in a tractor-trailer, the air inside will weigh 300 pounds (136 kg)!
- * Tell the students that because the atmosphere is so very high above the earth, the weight of the air at the surface of the earth is actually quite heavy. We'll see just how heavy this column of air is in this experiment.

Perform Experiment with the Students

Do the following:

- * Show the students the two gallon containers of water connected by a rope to a square piece of wood that is one square inch in size.
- * Tell the students that if we could contain all of the air in a column above this one inch piece of wood all the way out into space, its weight would be equal to the weight of the water in the gallon jugs.



- * Have each student walk up and try to pick up the water jugs by the square handle. (They don't have to actually pick it up; you just want them to feel the weight of the jugs.)



Conclusions

Tell the students the following:

- * Tell the students that they just tried to pick up 14.7 pounds. That's how much a one-inch square column of air square weighs. Pounds per square inch (psi) are an US/English unit of air pressure. Our 14.7 psi equals 1 atmosphere (atm) which is the standard unit measured as the average pressure at sea level.
- * If you want a comparison to the metric system, our demonstration of 14.7 pounds per square inch (psi) or 1 atmosphere (atm) in US/English is equivalent to the metric system pressure of 101.325 kilopascals (kPa), which is an amount of air that would weigh 6.67 kg.
- * Air pressure is created by the weight of the earth's atmosphere. Although we can't see air, the gas molecules still have mass, and gravity acts upon it. Meteorologists (weathermen and women) measure the air pressure which changes daily due to the heating and cooling of the earth's surface. When air gets warm, it expands, becoming less dense, and therefore pushes with less pressure. We can measure changes in atmospheric pressure by using a barometer. With regard to weather, high pressure generally means fair weather; low pressure generally means that storms are in the forecast.
- * The density of air is directly related to the temperature of the air. When air is heated, the molecules in it move farther apart and the air becomes less dense. One of the earliest forms of manned flight was due to this type of gas expansion! Hot air balloons use the fact that hot air expands and is less dense and thus lighter than the air around it. This is what allows hot air balloons to soar in the sky.
- * Because air is a gas, it moved and pushes in all directions. We do not feel the weight of the air because there is an equal force pushing from all directions. Also since air is a gas, it easily moves aside when you move your body through it. The inner pressure of our bodies pushing out

equalizes the air pressure pushing down on us. This is a good thing since the total air pressure on our bodies, depending on the weather and where you are on the earth, varies from 10 to 20 tons!

Additional Information If Needed: Technical Background

- Some barometers use long glass tubes filled with mercury inverted in a dish. Air pressing down on the surface of the dish forces the mercury up the tube. Normal air pressure can support a column of mercury about 760 mm high. When atmospheric pressure drops, the force of the air pushing on the dish isn't as great, so the column of liquid falls and we have a "falling barometer." When the atmospheric pressure increases, the mercury rises, thus a "rising barometer."
- Even though we can't feel it, air is constantly pressing down on us with a tremendous force, 14.7 pounds per square inch (100,000 newtons per square meters), to be exact! This was graphically demonstrated in 1654 when Otto von Gueicke, Burgmeister of the town of Magdeburg, Germany used a vacuum pump to remove almost all of the air from the space between two half-meter diameter hemispheres. The air pressure holding them together was so strong that two teams of horses couldn't pull them apart; when air was let back in, the hemispheres fell apart easily.
- We use air pressure all the time when we breathe. When our diaphragm moves down, air is pushed into our lungs from the outside, expanding the volume of the chest cavity. The diaphragm doesn't "pull" air in; it expands the volume of our lungs, and the air pressure fills the volume.
- Reference: Teacher's Guide for Show #1010 - "Air Pressure" on the Newton's Apple website and NASA's Quest web site

**Experiment 4: Proof of Air Movement – Goldenrod Paper
- How do we know air is really there?****Experiment Purpose & General Methodology**

- < The students will investigate molecular motion and the movement of gases in air.
- < This experiment will be done by each table, and will take about 3 minutes to complete.

Introduce the Experiment

Tell the students the following:

- * Ask the students if air stays still or moves. (All are experienced on this one. Wind, etc.)
- * Ask the students “If you add another gas to the air, how would you know it was there?” (Responses will vary.) Direct the students to the idea of adding a gas with an odor.
- * Ask students what gases do they know have odors. (Be ready for gross answers too.)
- * Ask students what would happen if you broke a bottle of perfume in one corner of the library room? Then ask why they would be able to smell it?
- * Tell the students that air moves due to molecular motion of the individual gas molecules. The molecules are constantly moving and bouncing around, like kernels in a popcorn popper. We are going to prove this by watching a chemical reaction occur when ammonia molecules move and then come in contact with a dye that changes color in the presence of ammonia.

Perform the Experiment Simultaneously with the Students

Do the following:

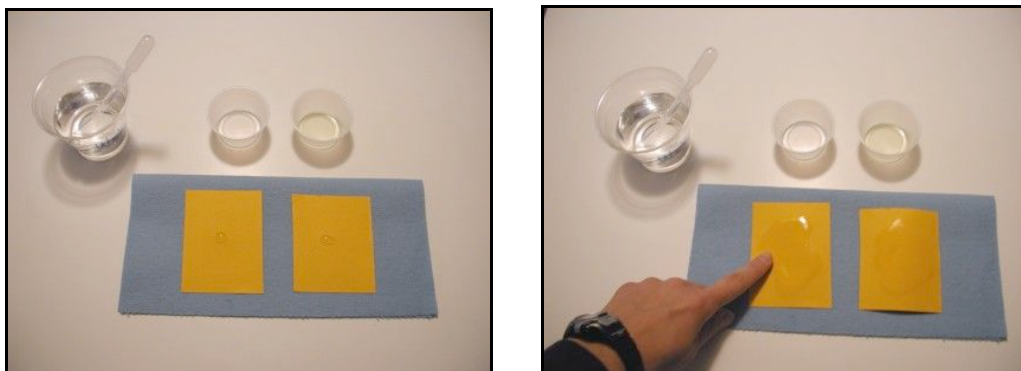
- * Have the students use the pipet and “water” cup (from Experiment 2) to add 2 – 3 pipets full of water to one of the portion cups.
- * Open the vial marked “ammonia” and pour about 5 ml of the ammonia solution into the other (empty) portion cup at each table.
- * While pouring, ask the students if they have ever heard the terms acids and bases? Let them know that in this experiment ammonia acts as a base in water. (Bases are good cleaning agents; this is why most of the parents probably have ammonia in their cleaning closet at home.) We use chemicals called ‘indicators’ to tell the difference between acids and bases. Indicators are molecules that are one color when acidic and a different color when basic.
- * Pick up one portion cup containing water and one portion cup containing the ammonia solution and have the students observe the color of the two solutions (both clear) and how they

Experiment 4

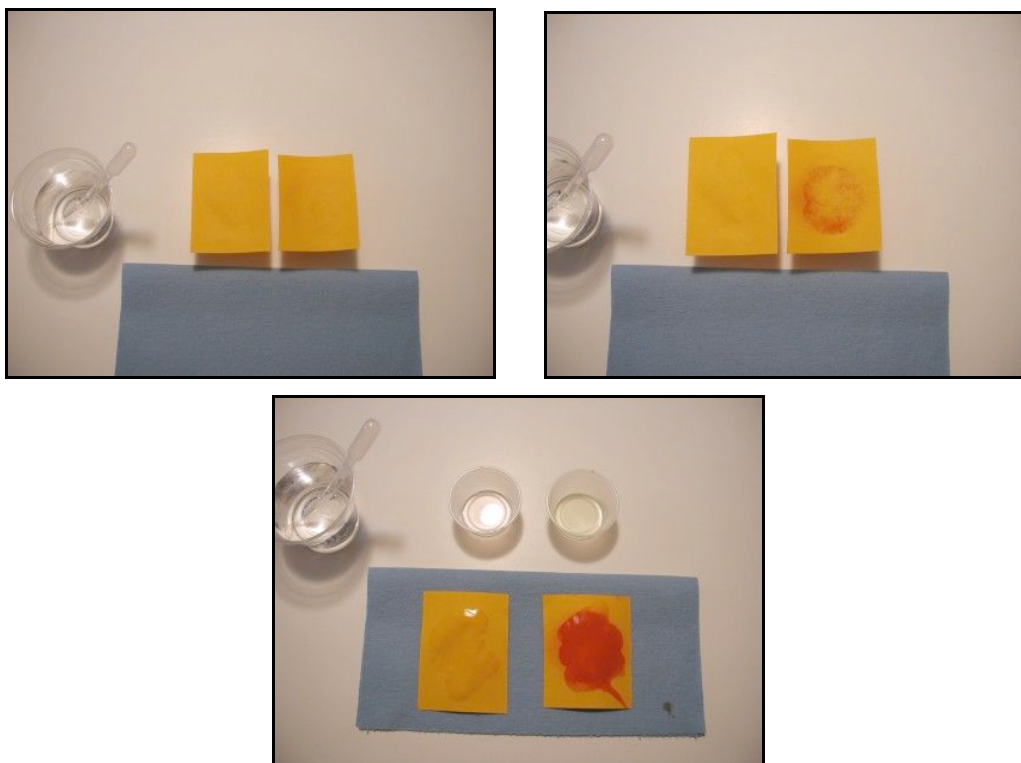
Demonstrator's Guide

can tell which is which from where they sit? (Note: In these pictures, the ammonia solution is "lemon-scented" and slightly yellow in color.)

* Tell the students that we will now wet the two pieces of goldenrod paper. Have one student at each table use the water pipet to place 3 – 4 drops of water on each piece of goldenrod paper and spread it around with their fingers. Have paper towels handy to wipe up excess water.



* Take the wet pieces of paper and place them, wet side down, over the two portion cups (one containing water, the other containing the ammonia) and observe them. The goldenrod paper above the container with the ammonia will turn red within about 15-30 seconds; the paper over the water will remain unchanged.



* Ask the students to explain. Explain that in water, ammonia is a base and that the dye used in the goldenrod paper acts as an indicator for acids and bases. To illustrate that it is the ammonia that is reacting with the indicator to make the red color, take a cotton swab, dip it into the ammonia solution, and draw a mark on the paper that was over the water. Since ammonia is a gas that dissolves in water to form a base, the indicator changes color when the ammonia solution touches the paper.



* So how did all of the other papers turn red when they never touched the ammonia solution in the cups? Explain that since the paper did not touch the ammonia, the ammonia must have moved from the surface of the liquid to the wet paper above it. This can only happen if part of the liquid ammonia evaporated into a gas and then traveled to the paper for the reaction to occur.

* Collect all of the cups now and pour the liquid into your liquid waste container (and cover if possible). Throw the cups into your solid waste container/trash bag. This is so the ammonia odor does not bother the students or other library patrons.

* Tell the students that you will come back to the paper in a little while to see if any other changes take place. Do any changes occur over time? (There will probably be less color as some of the ammonia evaporates during the rest of the presentations.)

Additional Information If Needed: Technical Background

- Indicators change color when going from acidic to basic solutions. They are usually weak acids in which the un-ionized form HA has a different color from the negative ion A^- . In solution the indicator dissociates slightly $HA = H^+ + A^-$. In acid solutions the concentration of H^+ is high and the indicator is largely undissociated HA ; in basic solutions the equilibrium is displaced to the right and A^- is formed. Other indicators are molecules which form complexes with other molecules, with the complex having a different color than the original molecule, or molecules that change conformation (and hence reflect light differently) based on their acidity, basicity, or exposure to electrical charge.

- When a bottle of perfume is broken in a corner of a room, the perfume vapors (or gas) will slowly move through the air in a random fashion. People closest to the bottle will typically smell the perfume before those farther away from the bottle. The perfume molecules move through the other molecules that make up the air just as one of us might move through a crowded room, 'accidentally' bumping into other people and not really traveling in a straight line.

Experiment 5: Solubility of Gases – Propulsion / Soda Fountain

Experiment Purpose & General Methodology

⟨ The students will observe the amount of gases stored in a liquid by observation of the propulsion effect once this gas is displaced from the liquid.

⟨ This experiment will be done as a demonstration and will take less than 5 minutes.

Introduce the Experiment

Tell the students the following:

✱ Hold up the unopened bottle of soda/pop. Ask the students to listen carefully as you open the bottle. Open the bottle just enough to hear the “hiss”, then recluse. Ask the students what makes this noise. (Escaping gases.)

✱ Tell the students: We already discussed in the goldenrod paper experiment that gases could be dissolved in liquids. We all have seen gases escaping out of a bottle of pop. Why does this happen? Pop is packaged under pressure and it is this pressure that keeps the pop carbonated. When the cap is opened, the pressure on the contents of the bottle suddenly decreases and when the pressure on a gas decreases it expands taking up more space. It is this sudden change in pressure and sudden expansion of the gas that forces the gas out of the container. Usually this gas has collected at the top of the can or bottle and when the container is opened it escapes with no more than a hiss.

✱ Ask the students how we can increase the release the gases from the pop. Most will know of shaking the bottle. If the bottle is shaken, the gas, which was at the top, is mixed through the pop. When you stop shaking the bottle, most of this gas returns to the top of the container. However, small bubbles of the gas get stuck all over the sides of the bottle. When the bottle is opened, and the overall pressure is lowered, these bubbles expand very quickly and try to force their way up and out of the bottle. To do this, they must push through the soda pop to the top and in doing so they force liquid out of the bottle in a very explosive and messy fashion.

✱ Tell the students that we will be releasing the gases in a different, but still exciting way.

Perform Experiment as a Demonstration

Do the following:

✱ Place the small tray somewhere where all the students can see it.

✱ Have paper towels nearby, just in case.

✱ Open the pop bottle and set it in the center of the small tray.

Experiment 5

Demonstrator's Guide

- * Show the students the Mentos mixed fruit candy.
- * Take the candies out of the bag. Ask the students to watch closely, and drop both candies together into the bottle of pop. (The pop will fountain up and out of the bottle into the tray.)



Adding Mentos candies.



Fountain starts.



Fountain over.

Conclusions

Tell the students the following:

- * Ask the students what made the original sound of the pop bottle opening. (Expanding gas.) Ask the students where this gas is located. (Dissolved in the liquid soda.) (You can also remind them of the goldenrod paper experiment that the gases were dissolved in the water.)
- * Ask the students what they think happened. What made the pop fountain out of the bottle? If they need a hint, tell them that we would have similar, albeit less dramatic, results if we added salt or sugar.
- * Tell the students that not only can gases be dissolved in a liquid but so can very small solids. All of these solids and gases take up space between the liquid molecules. We often add solid sugar to iced tea or coffee and it dissolves in the liquid. In this case we added a candy whose outside coating dissolves very quickly into very small particles in the liquid pop. This sugar and other substances take up space in the liquid. The gases in the pop are displaced by the sugar and other particles, and thus the gas is forced out of that same space. While liquids can contain solids and gases, only so much can be held by the liquid at any given pressure and temperature.
- * Just as air flows out of a balloon when you blow it up and let it go, and propels the balloon around the room, this expulsion of gas from a solution is another form of propulsion.
- * By the way, shaking up your soda pop does not have to result in an explosion of the pop as mentioned earlier. One way to prevent this from happening is to tap the sides of the container. This knocks the trapped bubbles off the sides of the bottle allowing them to collect at the top of the bottle. If you knock all of the bubble off the sides, the container can be opened without a

spray of soda. (This information was obtained from web sites including www.sciencetheatre.org at Michigan State University.)

Additional Information If Needed: Technical Background

- Why is a warm bottle of pop more likely to fizz over more than a cold bottle? Because gases are less soluble in liquids at higher temperatures. When a bottle of pop is warm, less of the carbonation is dissolved in the liquid. This increases the pressure of the gas in the bottle, and the warm bottle has a greater tendency to fizz over! One good reason to refrigerate your pop!
- Exact components of the Mentos candy coatings were not divulged by the manufacturer.

Experiment 6: Air Flow and Bernoulli's Principle – How do we fly? (Making Air Move Fast, Windbags)

Experiment Purpose & General Methodology

- < The students will learn about airflow and Bernoulli's Principle.
- < The paper strip and paper circle experiments will be done by each student; the windbag experiment will be done by each table.
- < All experiments combined should take 10 minutes to complete.

Introduce the Experiment

Tell the students the following:

- * We already learned that air has pressure that is pushing on our bodies all the time. But if the air is so heavy, how is it that airplanes can get off the ground and stay floating up in the air?
- * Let's do some experiments that help understand how air moves!



Perform the Experiment Simultaneously with the Students

Do the following:

- * Ask for a student (or students) to volunteer and have the student(s) come up to the front of the room.
- * Hand the student(s) a long, thin bag and ask them to blow it up like a balloon and count (to themselves) how many breaths it takes.
- * After the students have started blowing into their bags, take a bag for yourself and hold it about 12 to 16 inches away from your mouth. Take a deep breath and blow into the opening of the bag with one long breath. Just as you finish your breath, grab the top of the bag to hold the air inside.
- * Have the student volunteer(s) stop blowing into their bags and compare how many breaths it took for each of you. (The students will have taken many breaths, yours will have been just one!)

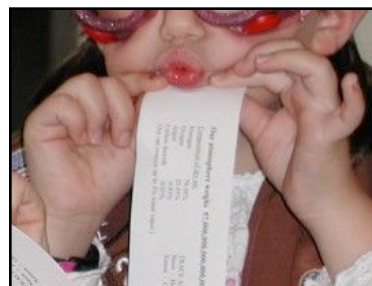


Experiment 6

Demonstrator's Guide

Student illustrating proper way to hold bag to blow it up in one breath.

- * Tell the students that when air is flowing and moving, it doesn't always behave the way we might expect.
- * Have the students return to their tables and pass out the bags so that each table has one. Explain how you held the bag and blew into it, then allow the students some time so that each student can try to blow up the bag with one breath.
- * Now have the students locate their strip of paper that was used in the "Components of Air" discussion.
- * Ask the students what they think will happen when you blow on a piece of paper.
- * Show the students how to hold the paper strip up to their mouths, just under the lower lip, between two fingers touching their skin, and blow.
- * Briefly discuss how the paper moved up, rather than down as might have been expected.
- * Next, have each student pick up a circle of paper with the metal clasp in it and a spool.
- * Ask the students what will happen if they blow through the spool onto the circle of paper.



* Show the students how to hold the spool to their mouths with the circle of paper at the bottom. The metal clasp should be centered in the hole at the bottom of the spool.

* Have the students take a deep breath and exhale in one long breath through the spool. As the students are blowing, have them take away their hands so that the paper floats under the spool.

Conclusions

Tell the students the following:

- * When air is moving quickly, it has less pressure.
- * When we blew into the bag with one long breath, the fast moving air from our breath was at a lower pressure and it carried additional air with it into the bag. In 1783, David Bernoulli, a scientist from Switzerland, was the first one to observe that fast moving air has lower pressure. We use the term "Bernoulli effect" to describe the phenomenon.

- * Airplanes make use of the Bernoulli effect to get off the ground and float in the air. The top of an airplane's wing is curved so that the air moves faster over it. Fast moving air has less pressure. The curve in the wing of the airplane creates a situation where there is lower air pressure above the wing than below it. Since the pressure below the wing is greater, it pushes the wing (and the airplane) up creating "lift". The lift conquers gravity and keeps the plane in the air.
- * With big enough wings, a 40-ton 747 jet can stay up in the air, just because of air pressure.
- * When we blew over the top of the piece of paper and blew through the spool, we created fast moving air, and therefore lift, which made the pieces of paper "float".
- * Tell the students that at the end of the program they may each take home their circle of paper and spool. Do not give them the long, thin shopping bags to take home, but let them know if they want to try the "wind bag" experiment at home, they can use any long, thin bag like a bread bag or newspaper bag. (If your kit has these types of bags, hold them up as examples.)

Additional Information If Needed: Technical Background

- With regard to airplanes, the angle at which the wing meets the air (the angle of attack) also contributes to lift. You can easily demonstrate this when you hold your hand out the window of a moving vehicle and change the angle at which your palm meets the oncoming air. If the surface of an airplane wing meets the air at an angle, the wing exerts a force on the air and the air exerts an equal force on the wing--an effect which Newton described in his third law of motion. The air passes over the wing and is bent down. Newton's first law says that there must be a force on the air to bend it down (the action). Newton's third law says that there must be an equal and opposite force (up) on the wing (the reaction). To generate lift a wing must divert lots of air down.



True airflow over a wing with lift, showing upwash and downwash.

Demonstrate by displaying the side view of a bent piece of paper.

- There are many other factors that influence lift: the shape and area of the wing, the velocity of the airplane, and even the density of the air. (From Newton's Apple Teachers Guides for Show

#1105 – Jumbo Jets and "Understanding Flight", by David Anderson and Scott Eberhardt, McGraw-Hill, 2001)

- More interesting information from <http://inventors/about.com>
- 400 BC: The discovery of the kite that could fly in the air by the Chinese started humans thinking about flying. Kites were used by the Chinese in religious ceremonies. They built many colorful kites for fun, also. More sophisticated kites were used to test weather conditions. Kites have been important to the invention of flight, as they were the forerunner to balloons and gliders.
- 1800-1850: Sir George Cayley is considered the father of aerodynamics. Cayley experimented with wing design, distinguished between lift and drag, and formulated the concepts of vertical tail surfaces, steering rudders, rear elevators, and air screws. Cayley designed many different versions of gliders that used the movements of the body to control. A young boy, whose name is not known, was the first to fly one of Cayley's gliders, the first glider capable of carrying a human.
- Orville Wright (1871-1948) and Wilbur Wright (1867-1912) requested a patent application for a "flying machine" nine months before their successful flight in December 1903. The craft soared to an altitude of 10 feet, traveled 120 feet, and landed 12 seconds after takeoff.

**Return to Experiment 4 – Proof of Air Movement
– Goldenrod Paper**

- * Return to the goldenrod paper and ask the students if they see any change in the goldenrod color. Why do they think it has changed?
- * Explain that some gases are soluble in water but they can also evaporate back into the air just like water will evaporate if you let it sit out for a long time. The ammonia and water molecules move around in the air now.



Experiment 7: Alka-Seltzer® Rockets

Experiment Purpose & General Methodology

- 〈 The students will use a reaction between Alka-Seltzer® and water to propel a film canister.
- 〈 The demonstrator and each student table will have one rocket. This experiment should take about 5 minutes to complete.

Introduce the Experiment

Tell the students the following:

- * From hot air balloons, to airplanes, to jets, man has learned how to move through the air with speed and precision.
- * In 1926, American engineer Robert Goddard was the first person to launch a liquid-fueled rocket. The rocket was fueled by a combination of gasoline and liquid oxygen which when burned created a powerful chemical reaction that produced hot gases. The expansion of the hot gases propelled the rocket 41 feet into the air at a top speed of 61 mph.
- * In the 1960's as we raced to travel to the moon, much more attention was given to propulsion by rockets. To rocket into space, we need to escape the earth's gravity! This requires a rocket that can travel at 25,000 mph (40,000 kph).
- * In this experiment, we will make a simple rocket that we can launch!

Perform Experiment as a Demonstration, then Simultaneously with the Students

Do the following:

- * Empty the pop from the tray in experiment 5.
- * Place the empty tray from experiment 5 and the additional small tray on the **floor**, centrally located, but as far away from the student tables as possible, and not directly under any lights. These trays will become the launch pads.
- * Be sure your students have their goggles on.
- * Have the students watch while you add the pieces of Alka-Seltzer to your film canister, cap tightly, place on one of the launch pads, and stand back. For fun, count down while waiting for your rocket to launch.



* Now, ask one student from each table to locate the film canister and the cup containing the pieces of Alka-Seltzer tablet.

* Ask the students, one at a time (or in pairs), to add the tablet to the film canister and snap on the lid as quickly as possible. Have the student to place the film canister on the launch pad, lid down. **Make sure that everyone is standing back.** Count down while waiting for the launch.



**CAUTION: THE ROCKETS ARE DANGEROUS. A MISFIRED
ROCKET COULD HIT A PERSON IN THE EYE.**

Note: Keep all spectators at least 10 feet away from the launch pad. Do not point the canister at yourself or anyone else.

Make sure all students have their goggles on.

* Repeat the launch with the other tables, one rocket at a time or alternating from the two launch pads.

Optional. If running out of time, the demonstrator may wish to launch only one rocket as a demonstration.

Conclusions

Tell the students the following:

* The ingredients in an Alka-Seltzer[®] tablet react with water to form a gas called carbon dioxide (CO₂). Carbon dioxide is the gas people exhale and plants use. It is also the gas that forms the fizz in pop.

* Gases expand to take up all available space.

* The formation of carbon dioxide gas exerts pressure on the closed film canister. The weakest part of the canister is where the lid and canister body meet. When the pressure builds, the lid pops off. The body of the canister is propelled upward. Many of today's jets and rockets still use expansion of gases as a source of propulsion; they just use better fuels and more of them.

Additional Information If Needed: Technical Background

- < Alka-Seltzer[®] tablets contain sodium bicarbonate (baking soda), citric acid, and acetylsalicylic acid (aspirin). When mixed with water, the base (sodium bicarbonate) reacts with the acids, forming sodium citrate, sodium acetylsalicylate, and carbon dioxide.
- < The sodium citrate is the buffering agent that acts as the antacid.

Experiment 8: Marshmallow Syringes – Changes in Air Pressure

Experiment Purpose & General Methodology

- 〈 The students will learn about gas pressure by observing a marshmallow in a syringe.
- 〈 Each table will share one syringe but each student will do the experiment. This experiment should take about 10 minutes.

Introduce the Experiment

Tell the students the following:

- * Tell the students that “to pressurize” means to apply pressure. Ask them what they think pressure means. (Some may answer “stress” due to the pressure their parents are under, but we are looking for an answer more like “the push of a gas on an object” like the push of air on the earth.)
- * Ask the students if they have ever been up in the mountains. Perhaps several have had trouble breathing - this was due to low air pressure. Air pressure is higher at sea level due to the column of air above, compressing the molecules of air together. High up in the mountains, there is less air pressing down, so the molecules are farther apart and the pressure is lower.
- * When the molecules that make up air are close together, we have high pressure. When the molecules are farther apart, the air pressure is lower. If we could take all of the air molecules away, we would have a vacuum.
- * Astronauts sometimes work in the vacuum of space, where there is no atmospheric pressure since there is no atmosphere. But human bodies are used to the atmospheric pressure here on earth, so special suits are needed in space.
- * Ask the students what is in a marshmallow. (Hopefully, eventually they will get around to air.) Our bodies also contain a lot of air.
- * Tell the students they will learn about the power of pressure and its effect on the air in a marshmallow.

Perform Experiment Simultaneously with the Students

Do the following:

- * Pick up your syringe and have one student at each table pick up their syringe. Show the students how the syringe works and have the students do as you do.
- * Remove the cap (if necessary; see note in next step), then pull air in and push it out of the container. Have the students



feel the air coming out of the end of the syringe.

* Push all the air out of the syringe. Replace the cap. Pull on the plunger to show how difficult it is to remove. Tell the students they are creating low pressure inside the syringe.

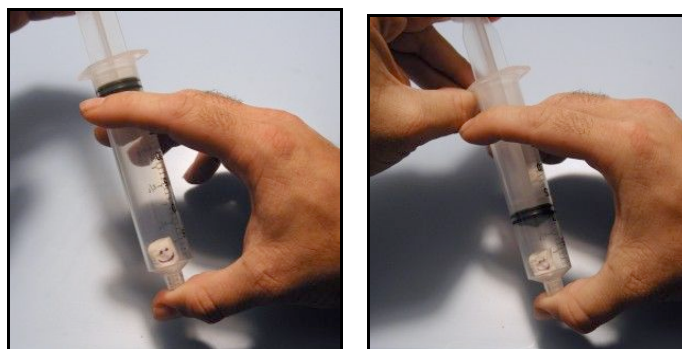
Note: Only some of the syringes are the luer-lock type that seal. If the cap to the syringe does not adequately seal the air (or if there is no cap, which may be the case for some), the students should hold their thumb or other finger over the opening to create the seal in place of using a cap.

* Remove the cap. Fill the syringe with air to the 30-ml mark. Replace the cap. Push on the plunger to feel the pressure needed to move the plunger.

* Remove the cap and the plunger from the syringe. Place one marshmallow (smiley face optional) inside the syringe. Replace the plunger and move it until it just touches the marshmallow. Replace the cap. Pull back the plunger. What happens to the marshmallow? [Answer: the marshmallow expands]. Move the plunger in and out a little to do it over again. Remove the cap and fill it with air, recap and move the plunger downward. What happens to the marshmallow? [Answer: the marshmallow shrinks to smaller than its normal size].



Marshmallow expanding in reduced pressure.



Marshmallow shrinking in increased pressure.

* Allow time for each student to explore the concept of pressure with his or her marshmallow.



Another view – Expanding



Another view - Shrinking

Conclusions

Tell the students the following:

- * The marshmallow expanded because the volume inside the syringe increased and the pressure inside the syringe decreased.
- * While a marshmallow has the strength of being able to withstand great changes in the pressure around it and survive, though it may change shape a bit, an astronaut in space certainly cannot! Many objects could be exploded or squished if the pressure was too high or too low. This is why we need special equipment to explore high-pressure regions deep in the ocean, or low-pressure regions in space. Astronauts wear special suits not only to supply them with air to breathe but also to protect them from the vacuum of space.

Additional Information If Needed: Technical Background

⟨ Marshmallows are as old as the pyramids. The Egyptians first discovered “althea” or “mallow root”, a plant that grew in the marshes along the banks of the Nile. Eventually, “marsh” and “mallow root” became a single word—marshmallow. But it was the French in the mid-nineteenth century that began to sweeten and whip mallow root into a light and fluffy confection. Today’s marshmallows do not contain mallow root. They consist of sugar, cornstarch, gelatin, and lots of air.

⟨ Pressure is force per unit area (such as pounds per square inch or psi).

⟨ Liquids boil at lower temperatures when the air pressure is lowered; this is why some recipes call for different baking times at different altitudes.

⟨ At the low pressure of space, the liquids in our bodies would boil. Spacesuits are pressurized to only 4.3 psi but contain higher levels of oxygen. Spacesuits can also endure the 250 degrees

Fahrenheit when in the sunshine and –250 degrees when out of the sun for a long time.
<http://vesuvius.jsc.nasa.gov/er/seh/suitnasa.html>

Experiment 9: CO₂ Detection

Experiment Purpose & General Methodology

- ⟨ The students will discover that the carbon dioxide we exhale is soluble in water to create an acid that will cause an indicator to change colors.
- ⟨ This experiment will be done per table. The initial introduction and experiment will take 5 minutes to complete.

Introduce the Experiment

Tell the students the following:

- * Astronauts in space need to take a suitable atmosphere along with them in their ships. They also need to mix gases from tanks when they are wearing space suits. If the gases are not mixed correctly they can become ill or even die.
- * One of the important gases to monitor and regulate is carbon dioxide which we exhale as part of our normal respiration. The level of carbon dioxide we are exposed to here on earth is 350 ppm (or 0.035% of the total air volume). If the amount of carbon dioxide we breathe gets to 30,000 ppm (or 3%), we can start having health problems. This can be serious business if you are in outer space! Although they have more sophisticated devices for detecting actual amounts of carbon dioxide, we here on earth have a simple way of detecting its presence.

Continue:

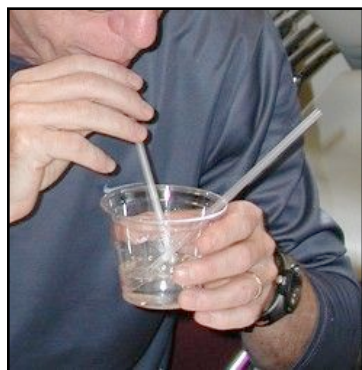
- * Ask students what chemicals are in water. Students may know that there is H₂O but do they know of the other gases that are dissolved such as oxygen (fish do not breathe water).
- * Explain to the students that other gases can also dissolve in water. Remind the students of the experiment they did earlier where the ammonia dissolved in water. Burning fossil fuels can add nitrogen oxides and sulfur oxides into the air. These react with water vapor in the air to form acids so we have “acid rain” in some areas of the county where these fuels are burned.
- * Tell the students that carbon dioxide is another gas that dissolves in water.
- * Ask the students “If you add a gas to the water, how would you know it was there?” After the earlier experiment students may come up with the idea of an indicator.
- * We are now going to use a different indicator to prove the presence of carbon dioxide.

Perform Experiment Simultaneously with the Students

Do the following:

* Have one of the students distribute a straw to each person at the table.

* Demonstrate that you will leave the cup marked "H₂O" alone while the students will blow into the water in the cup labeled "CO₂". Inform the students that they take in oxygen from the air when they breathe in. Their bodies use the oxygen and convert it into carbon dioxide which is then expelled when they breathe out.



* Have students each take a turn blowing through their own straw into the cup labeled "CO₂" for about 30 seconds.

* Ask the students: "What do you think happens when the carbon dioxide you exhale bubbles through the water? Does it stay (dissolve) in the water? Does it all come out of the water as bubbles of gas?"

* Indicate to students that you will discover if any carbon dioxide dissolved in the water by comparing the cup marked "water" to the cup you blew into by adding an indicator.

* Add a squirt of indicator to each table, and then do the same to each of tables (the two pipets contain Ask students to compare the colors there a difference?

Note: In the picture, the cup left; dioxide added is high, on the right.



cup on the demonstrator's the cups on the student enough for the 14 cups). in the two containers. Is

with just water is on the the cup with carbon

Conclusions

Tell the students the following:

* After adding our indicator, we can see that there is a color difference between the cup of water and the cup of water containing the carbon dioxide.

* Explain that when carbon dioxide is dissolved in water, it produces carbonic acid. As we discussed before, carbon dioxide is the gas that comes out of solution when you open a bottle of soda pop. However, some of the carbon dioxide remains dissolved in the soda pop and forms carbonic acid; it is this dissolved carbon dioxide (carbonic acid) that gives the tart taste to "pop".

* In an earlier experiment when we added ammonia gas to water it turned into a basic compound causing the indicator to change color. In this experiment, we added carbon dioxide to the water, and the carbon dioxide dissolved in and reacted with the water forming an acid called carbonic acid. This carbonic acid makes our water solution acidic which we detect as a color change with our indicator.

Additional Information If Needed: Technical Background

- Tell the students and parents: You can do this same experiment at home using a few drops of a natural indicator like grape juice or the juice of a red cabbage. After you do the experiment, put the cup with the indicator into the microwave for 15 seconds and see if you notice a change back towards the original color. Carbon dioxide, like most gases, is less soluble when the temperature is higher. That is why you keep your opened bottle of “pop” in the refrigerator.

- From www.webmd.com and the American Maritime Safety Authority:

Three forms of carbon dioxide exist in the blood: bicarbonate HCO_3 , carbonic acid H_2CO_3 , and dissolved carbon dioxide CO_2 . High values can increase blood pH, a condition called metabolic alkalosis. (A normal level is 23–29 millimoles per liter (mmol/L).)

Carbon dioxide (CO_2) is naturally present in the atmosphere at levels of approximately 0.035% (only 350 ppm). Although short-term exposure to CO_2 at levels below 2% (20,000 ppm) has not been reported to cause harmful effects, CO_2 is an asphyxiant and toxic at high concentrations. At concentrations of 3% (30,000 ppm) by volume in air, it causes increased blood pressure and pulse rate, and also causes excitation and reduced hearing. At concentrations of about 5% volume, it causes dizziness, confusion, decreased mental performance, and difficulty in breathing. At 8% it causes headache, sweating, dim vision, tremor, and loss of consciousness after exposure for between five and ten minutes. Concentrations above 10% can be fatal. The gas is colorless and odorless and does not give any warning of its presence in an asphyxiating concentration.

Closing Session

Close Demonstration

- ⟨ Thank the students and parents for coming to this year's demonstration and learning about the chemistry of the earth's atmosphere and beyond. Tell the students that you will now collect the goggles and give them some items to take home.
- ⟨ Collect the goggles and hand out the 'Experiments To Do at Home & Book List' and the NCW activity newspapers.
- ⟨ Tell the students that you have only 10 copies of ChemMatters magazine, which is written for older children, and that if they have an older brother or sister or good friend that they may want to take one home for them.

Clean up

After the students leave, clean up the room

- ⟨ Return items borrowed from the library to a librarian. Give any leftover literature to the librarian.
- ⟨ Collect the film canister "rockets" and rinse with water. Shake off as much water as possible. Place them into one of the gallon-sized zipper bags (since they will be wet), and seal the bag. Place this into the large mailing envelope to be returned to XXX.
- ⟨ Collect the syringes, plungers, and caps and place these into a large mailing envelope to also be returned to XXX.
- ⟨ In the liquid-waste gallon jug, combine all water first; use a funnel to prevent spilling. This liquid waste can be put down the sink safely with running water.
- ⟨ All solid waste can be collected in the large garbage bag and thrown into the regular trash.
- ⟨ If you are performing another demonstration for this year's National Chemistry Week, sanitize the goggles between demonstrations with a dilute bleach solution as instructed in the written directions found on the inside cover of the goggle container. Be sure to dry them with soft cloth to prevent scratching.
- ⟨ If you are finished performing your demonstration(s) for this year, place the used goggles into their box. (There is no need to clean them when you are through. Our committee will clean them for the next year and/or for other programs.)
- ⟨ Complete the Feedback Form, place it into the collection envelope and seal the envelope.

Appendix

A. Material Safety Data Sheets

None necessary. All materials can be purchased at local stores.

B. Example of Air Components sheet

Our Atmosphere Weighs	57,000,000,000,000 Tons	(57 quadrillion tons)
Composition of dry air:		
Nitrogen	78.08%	
Oxygen	20.95%	
Argon	0.93%	
Carbon dioxide	0.03%	
Trace Amounts:	Neon, Helium, Krypton, Xenon, Ozone, Radon	
Air contains up to 3% water vapor		

C. Kit Contents – Supplemental List of Solutions and Special Supplies

The following is detailed information that can be used to recreate this demo kit in the future. Tips are listed with the number corresponding to their experiment number in this guide.

#2 For the egg cartons, only 6 compartments are needed; Styrofoam is preferred over cardboard. Alternatively, use six small plastic cups.

#3 Use enough water to fill jugs to measure 14.7 lbs.

#4 Goldenrod paper is available through Educational Innovations or office supply stores as Astrobrights Galaxy Gold.

#6 Long thin bags are sold by Educational Innovations as “wind bags”. Alternatively, use bread or newspaper bags. Any spool can be used as long as the ends are solid. If using a plastic spool, the paper cover should be in place. The paper circle should be somewhat larger than the spool diameter.

#7 Film canisters from “Fuji” work best since the cap pops off easily under pressure. Pom-pom pilots are each made from felt or foam feet, pom-pom, and wiggle eyes.

#8 Plastic syringes are available from Educational Innovations or other lab supply company.

D. Air Pressure Set-Up Diagram

Two one-gallon milk or water jugs (cleaned), strong string or rope, 1 inch square with hole.

14.7 pounds of water is equivalent to 226 ounces. On a standard milk jug, mark each of the two jugs with a fill line $6 \frac{5}{8}$ inches from the bottom.

