The Properties of Air

In the first lesson of the Clean Air Campaign's "Elements of Air Pollution" unit, students will play a game to learn relevant vocabulary words and complete a series of hands-on investigations to explore air. Through these experiments they will discover the properties of air, test for the presence of carbon dioxide, observe the results of plant transpiration and animal respiration, split water into hydrogen and oxygen, build air cannons and Bernoulli balls to observe how air moves, and remove the oxygen from a sample of air to determine what percentage of the atmosphere it comprises. Pre-requisite: Students should have been introduced to the periodic table, elements, and compounds before beginning this lesson. In the next lesson in this unit, students will apply knowledge gained in this lesson regarding the properties of air, to investigate how air becomes polluted, how air pollution can be reduced, and how its effects can be mitigated. (Environmental Education)

Education Committee	*The Clean Air Campaign®*	*Fulton*	*EEinGEORGIA.org*

Primary Learning Outcomes

How do we know air is there? What are some properties of air? How does air move? How are the properties of air inter-related? Does gas have mass? How is the motion of gas molecules affected by mass and temperature? What are the effects of mass, pressure, volume & temperature on a gas? Can water be split into gases? How do we know that humans exhale carbon dioxide?

Additional Learning Outcomes

What gases make up the air in our atmosphere? What can we learn about the properties of air, which will help us understand more about air pollution?

Assessed GPS Standards:

Grade: 8

Science Standards:

S8P1 a-f: Students will examine the scientific view of the nature of matter.

a. Distinguish between atoms and molecules.

b. Describe the difference between pure substances (elements and compounds) and mixtures.

c. Describe the movement of particles in solids, liquids, gases, and plasma states.

d. Distinguish between physical and chemical properties of matter as physical (i.e., density, melting point, boiling point) or chemical (i.e., reactivity, combustibility).

e. Distinguish between changes in matter as physical (i.e., physical change) or chemical (development of a gas, formation of precipitate, and change in color).

f. Recognize that there are more than 100 elements and some have similar properties as shown on the Periodic Table of Elements.

Procedures/Activities

Step: 1 Duration: Teacher Preparation
Refer to the Materials List, attached below, to assemble supplies for the lesson. Print, laminate and cut apart the vocabulary cards for use at Step 3. Print and make a copy of the Lab Report, attached at Step 4, for each student. Obtain helium-filled balloons (one plus back-ups in case of breakage) and unfilled latex balloons of the same size and kind (three per group), to be used for activities at Step 6.

Order 100 – 500ml Bromthymol Blue indicator solution (0.04%; aqueous) from a science supply house approximately one week in advance, and pour into dropper bottles to be used at Step 7. (See Web Resource below for ordering information). Pre-drill a hole in the center of the metal end of the cylindrical oatmeal container(s) to be used at Step 9. If a drill is not available, substitute a container such as a soup can, use a can opener to remove both ends, cut a cardboard disc of the same diameter with a hole in the center to replace one end and tape the cardboard disc in place. Use pruning shears to snip off eraser ends of two or more wooden pencils and sharpen both ends of the pencils for use at Step 10.

Read the background information linked throughout the lesson, in preparation for leading the debriefing at the end. Divide the class into six groups of lab partners. Set up lab activities at each of six stations. Place the appropriate Investigation Station sign (attached below) at each location. Groups of lab partners will rotate through the stations, spending 15 minutes at each. (Alternative: For a large class, it may be preferable to have eight groups of lab partners to keep group-size small.

This can be accomplished by setting up computer activities associated with Investigation #2 (Step 6) and Investigation #4 (Step 8) as separate Investigation Stations #7 and #8. Note: The number of stations must equal the number of groups. Each station added increases lesson duration by 15 minutes).

Web Resources for Step 1

Title: A Source for Bromthymol Blue Indicator Solution
URL: http://www.flinnsci.com
Annotation: Bromthymol Blue Indicator Solution is available from any science supply house. It is suggested that teachers use any vendor with which their school district has a discount and an arrangement for free shipping. The following ordering information is provided for convenience. Open the Flinn Scientific Web page, click on Flinn Ordermaker and download the file (requires Adobe Acrobat) to place an order online OR call 800-452-1261 OR fax 866-452-1436. Order Bromthymol Blue Indicator Solution, 0.04%, aqueous, which is available in the following quantities: 100 ml = Item # BO173 (approx. $3); 500 ml = Item # B0047 (approx.$6); or 1L = Item # BO228 (approx. $9). Chemicals can be shipped to school addresses only.

Title: A Source for Hand Warmers
URL:
http://heatreliefdepot.com/catalog/index.php?manufacturers_id49
Annotation: Hand warmers are generally available for less than $2 per pair at many hardware, sports and camping stores. If not in available locally when needed, they may be ordered from Grabber Performance Group in quantities of 10 pairs (order #HW10) for less than $20 or 40 pairs (order # HW40) for less than $65. There is no charge for shipping by regular ground delivery.

Attachments for Step 1

Title: Investigation Station Signs **FileName:** Investigation Station Signs.doc
Description: Print out the signs and fold each in half like a tent to set on the table with the corresponding lab activity. (Station signs 7 and 8 are optional, depending on size of class and number of groups selected).
Title: Materials List for Lesson **FileName:** Materials List for The Properties of Air.doc
Description: Refer to the Materials List attached at this step to assemble all the supplies necessary.

Step: 2 Duration: 25 minutes

"Get Off My Back" Vocabulary Game

Explain to students that before they can conduct investigations about atmospheric gases, they must be familiar with some basic terminology and symbols. Distribute the Word Bank and allow students 10 minutes to use reference materials such as dictionaries, encyclopedias and science textbooks to look up and record definitions of any words they do not know.

Next, distribute word cards to the class by using a clothespin to attach a card to the back of each student's shirt, without letting the word be seen by the student wearing the card. Tell students that they may mingle and each student may provide one clue to each other student, regarding the word he or she is wearing. If a student guesses the word on his/her back correctly from the clue, it may be removed. When all the words have been correctly guessed or 10 minutes has elapsed, call the class together again and collect the cards to review the definitions. Assign a word monitor to look up and confirm the definition of each word as it is reviewed.

Attachments for Step 2

Title: Answer Key for Word Bank **FileName:** Answer Key for Word Bank.doc
Description: Suggested answers for the Word Bank Worksheet and "Get Off My Back" game.
Title: Get Off My Back Word Bank Worksheet **FileName:** Get Off My Back Word Bank Worksheet.doc
Description: A copy of this Word Bank is to be distributed to each student and used to record meanings of unfamiliar words.

Title: "Get Off My Back" Word Cards **FileName:** Get Off My Back Word Cards.doc
Description: Vocabulary game cards to be printed, laminated, cut apart and distributed -- per the directions above.

Step: 3 Duration: 20 minutes

Demonstration Labs

Two lab activities will take time to develop results, and should be started before students rotate through the investigation stations. Demonstrate these experiments for the class. They should be observed and discussed at the end of the lesson.

Demonstration Lab A: How Much Oxygen is in the Air?

Use the Web link below ("Estimating the Percentage of Oxygen…") as a resource for setting up this lab. Tape a wet, disposable hand warmer to the inside bottom of a beaker (or glass jar with straight sides) and invert the beaker over a deep saucer of water. Explain that as the oxygen chemically reacts with iron in the hand warmer to form iron oxide (rust), O2 gas will occupy less and less space. This

creates an area of low pressure into which water from the saucer will rush, partially filling the inside of the jar. Ask students to brainstorm how they could estimate the percentage of oxygen, which had been in the air, once the water level stops rising inside the beaker. (Since water takes the place of oxygen, the proportion of the beaker, which is filled with water should be the proportion of oxygen, which was previously in the air. In other words, if the water level were to reach 1/2 way up the beaker, the proportion of oxygen in the air would be about 1/2, or 50%). Have the class observe this experiment at the end of class. It takes about 20 minutes to start working and more than two hours to finish reacting.

Demonstration Lab B: What Happens to Water Pulled Up Through Plant Roots? Take a small, green broad-leafed plant or a twig with ten or more green leaves and immediately seal it in a zip-top bag OR seal the end of a leafy branch in a zip top bag without cutting the branch off the tree. Place the bag in the sun or near a very sunny window. (Fluorescent lighting will not work). Tell students they will observe the specimen again, after rotating through the labs. Invite them to predict what changes will be observed by the end of class.

Web Resources for Step 3

> **Title:** Estimating the Percentage of Oxygen in the Atmosphere
> **URL:** http://vortex.plymouth.edu/atmosphere/compose.html
> **Annotation:** This Web site provides illustrated instructions for making the device for Demo Lab A; and tells how it can be used to estimate the percentage of oxygen in the air.

Step: 4 Duration: 10 minutes

Introduction to Investigation Stations

Start a discussion by asking students: “Is the space around us is empty or filled?” “What is air?” Challenge students to think of ways to prove whether air exists. Hint: Can students think of any properties of air, which could be measured? (Properties of air include mass, volume, density, pressure, temperature and viscosity or compressibility. It is not necessary to identify all of the properties at this point.) Record student responses on chart paper and tape paper on the wall for future reference.

Assign each group of lab partners to a different investigation station. Tell students that they will have 15 minutes to do each investigation and to complete a corresponding section of the Lab Report. Explain that 15 minutes will be timed, and when time is called, each group should move clockwise to the next station. (A kitchen timer is useful for keeping the activities on schedule). Before moving, the group should disassemble any devices built during the investigation and leave the area clean. Distribute Lab Reports and clipboards and emphasize that every individual must turn in a completed Lab Report, although partners may collaborate on the answers. Option: To ensure that predictions are made before the

experiments are conducted, the teacher may ask students to read the lab report and fill in the “Prediction” section for all investigations before dismissing the groups to the various Investigation Stations.

Web Resources for Step 4

Title: Ideal Atmosphere Interactive Simulation
URL: http://www.chem.uci.edu/undergrad/applets/canonical/canonical.htm
Annotation: The Lab Report contains a link for this interactive Web site, where students can manipulate a model to learn more about the relationships among mass, temperature and volume of gases in the atmosphere. A computer browser (e.g. Netscape Navigator) must support Java applets to run this simulation.
Title: Gas Lab Animation
URL: http://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html
Annotation: The Lab Report contains a link for this Web site where students may freeze any two variables to view an animation of the effects of the remaining two variables on a gas.
Title: Got Gas?
URL: http://www.tryscience.com/experiments/experiments_electrolysis_online.html
Annotation: The Lab Report contains a link for this Web site, to which students may refer for directions on how to separate hydrogen and oxygen from water.

Attachments for Step 4

Title: Lab Report for The Properties of Air **FileName:** Lab Report for Properties of Air.doc
Description: A copy of this Lab Report should be distributed to each student. Note that the last page is only needed if 8 groups of lab partners are formed and 8 lab stations set up. The Lab Report will be used to record predictions, observations and conclusions regarding the lab investigations. It contains Web addresses, which students will need for lab activities at Steps 6, 8, and 10 (also linked below). Every student should complete an individual Lab Report, although lab partners may collaborate on their answers. Graphics courtesy of Microsoft Design Gallery and The Clean Air Campaign, with permission.

Step: 5 Duration: concurrent with Steps 6, 7, 8, 9, and 10. (Six 15-min sessions for a total of 90 minutes or 8 sessions for 120 minutes)

Investigation # 1: How Do We Know Air is There?

For this station, provide an Ehrlenmeyer flask (or beaker or glass jar), a funnel with a diameter across the top which is somewhat larger than the diameter of the of the flask, a package of plasticine for each group (sometimes marketed as “Blue Tac” or “Yellow Tac”), a pitcher of water, (blue) food coloring, a pencil and lots of paper towels.

Students will put the funnel in the top of the flask and seal the connection between the funnel and the flask with plasticine. (Modeling clay does not make as tight a seal and works less well). No air should be able to escape from the flask, except through the funnel. One student will color the water in the pitcher with a few drops of blue food coloring, to make it easier to see. Next, each student should predict what will happen when water is poured in the funnel. Then, a student will pour water from the pitcher into the funnel. After pouring, results should be observed and recorded. Each student should predict what will happen if a hole is poked in the plasticine. Then a student will use a pencil to make a small hole anywhere in the plasticine. Students will observe and record the results.

Step: 6 Duration: concurrent with Steps 5, 7, 8, 9, and 10

Investigation # 2: Gas and Mass

For this station, provide a meter-long, 1 cm (¼”) diameter wooden dowel rod, four identical, round balloons per group, one of which is filled with helium, a ball of string, scissors, tape, and a large safety or hat pin.

Part A: Does Gas Have Mass?

Students are to balance the dowel rod horizontally with the mid-point resting on someone’s finger. Next, they will blow two balloons up to equal size and use string to hang the balloons from opposite ends of the dowel. Students should predict what will happen when a balloon is popped; then pop a balloon; and observe and record the results.

Part B: Do All Gases Have the Same Mass?

Students should predict what will happen when a helium-filled balloon is suspended by string from one end of the dowel and a balloon blown-up by a student to the same size is suspended from the other end. Students will attach the balloons; then observe and record results.

Part C: How Are Gas Molecules in the Atmosphere affected by Mass and Temperature?

(Note: In the six group / six station scenario, this activity will be non-assessed, optional Part C of Investigation Station # 2. If eight student groups and eight investigations are preferred, this activity should be set up separately as Investigation Station # 7)

Using an Internet-connected computer, open the “Ideal Atmosphere Simulation” Web page, linked below. Students may manipulate this simulation of gas molecules in the atmosphere to control for mass, temperature and number of molecules. They will observe how these physical properties of gas relate to one another, and develop a theory for how there may be less hydrogen and helium in the atmosphere today than there was many millennia ago.

Web Resources for Step 6

Title: Ideal Atmosphere Interactive Simulation
URL: http://www.chem.uci.edu/undergrad/applets/canonical/canonical.htm
Annotation: Students may manipulate this interactive Web site to learn more about the relationships among mass, temperature and volume of gases in the atmosphere. The computer browser (e.g. Netscape Navigator) must support Java applets to run this simulation

Step: 7 Duration: concurrent with Steps 5, 6, 8, 9, and 10

Investigation # 3: How Do We Know that Humans Exhale Carbon Dioxide (CO2)?

For this station, provide a clear cup and straw for each student, and dropper bottle(s) filled with bromthymol blue (BTB), which is an indicator solution for carbon dioxide.

Students will pour 100 ml water into a beaker (or measure 100 ml water in a graduated cylinder and pour it into a clear plastic cup), add drops of BTB until the color changes to blue, and then blow through the straw into the water. BTB turns yellow in the presence of carbon dioxide. Students will predict, observe and record the results.

Web Resources for Step 7

Title: MSDS for Bromthymol Blue, Aqueous
URL: http://www.gfschemicals.com/Search/MSDS/2043MSDS.PDF
Annotation: The MSDS (Material Safety Data Sheet) for Bromthymol Blue provides details on hazards, safety procedures and disposal. Note that there are “no health hazards by normal means of exposure.”

Step: 8 Duration: Concurrent with Step 5, 6, 7, 9, and 10

Investigation #4: How Are the Properties of Air Inter-related?
For this station, provide one or more round balloons per group, permanent marker, tape measure, a source of heat, such as a hot plate (preferred) or lamp, a source of cold, such as a bowl of ice and an Internet-connected computer.

Part A: What is the Relationship between Air Temperature and Volume?
Students will blow up a balloon, draw a face on it, measure the circumference (making a mark to show exactly where tape measure encircled balloon), expose the balloon to heat for two minutes, compare circumference measurement and observe any changes; expose it to cold for two minutes, compare circumference measurement and observe changes again. It is suggested that this investigation be set up in an area where an Internet-connected computer can be used to view the interactive Gas Lab Animation Web site (linked below), following the experiment.

Part B: What are the Effects of Mass, Pressure, Volume and Temperature on a Gas?
(Note: If eight student groups and eight investigations are preferred, this activity should be set up separately as Investigation Station # 8. In the six group / six station scenario, this activity will be non-assessed, optional Part B of Investigation Station # 4.)

Students will use the interactive "Gas Lab Animation" Web site to explore how any two properties of air relate to each other. Variables (properties of air) in this animation include mass, pressure, volume and temperature. Students should be able to determine which pairs of properties have a direct relationship (when one increases, the other increases) and which pairs of properties have an inverse relationship (when one increases, the other decreases).

Web Resources for Step 8

> **Title:** Gas Lab Animation
> **URL:** http://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html
> **Annotation:** Students may freeze any two variables to view an animation of the effects of the remaining two variables on each other in a gas.

Step: 9 Duration: Concurrent with Step 5, 6, 7, 8, and 10
Investigation #5: How Does Air Move?
For Part A, provide cylinders such as empty rolled oats containers (or coffee cans, plastic buckets or garbage cans), enough latex or plastic to cover the end of each container (e.g. balloon or shower curtain liner), scissors, rubber bands and duct tape. A hole should have been made in the end of the cylinder, per Step 1. For Part B, provide two ping-pong balls, a roll of tape, string, scissors and a 1 cm X 1

meter dowel rod. For Part C, provide a capped, empty plastic bottle and hot water.

Part A: How Does A Compression Wave Move through Air?
Students will cut a large balloon and stretch it over the open end of the oatmeal cylinder (or cut a shower curtain liner to cover the end of a larger container) and secure the balloon or plastic in place. Some slack enhances the effect as long as the plastic is sealed along the sides of the container. Students will smack the plastic-covered end with an open palm to send a compression wave through the hole in the opposite end of this “air cannon".

Part B: How Does Pressure Affect the Movement of Air?
The station sign reminds students of Bernoulli’s Principle: As the speed of a moving fluid increases, the pressure within the fluid decreases. Students will suspend two ping pong balls from a horizontal dowel rod about five cm (two inches) apart and predict what will happen when air is blown between them. Then, they will take turns using the air cannon(s) to shoot a stream of air between the balls, observing and recording results. Air moving between the balls has lower pressure, so the balls are pushed into the middle by still air of higher pressure on the opposite side of the balls.

Part C: How Does Temperature Affect the Movement of Air
Students will predict what happens when air in a plastic bottle is heated, sealed and then cooled. Next, they will observe the results. When the air cools, it contracts and the sides of the bottle collapse inward.

Web Resources for Step 9

> **Title:** Bernoulli’s Principle Animation
> **URL:** http://home.earthlink.net/~mmc1919/venturi.html
> **Annotation:** Teacher background information which may be useful for debriefing this activity later. This Web site illustrates how Bernoulli’s principle works with an animation.

Step: 10 Duration: Concurrent with Steps 5, 6, 7, 8, and 9
Investigation #6: Can Water Molecules be Split into Hydrogen and Oxygen?
For this station, provide a beaker of salt water (or clear jar with straight sides, such as one which held salsa), two pencils, sharpened on both ends, a lantern battery, two 15 cm (6 in) pieces of bell wire and a piece of cardboard (which students will cut and use as a lid for the beaker, through which the pencils will extend).

Students will connect a wire from a contact (pencil lead) to the positive terminal of the battery and from the other contact (second pencil) to the negative terminal. They will predict and observe the results. Set up this investigation in an area where an Internet-connected computer could be used to view directions and an animation at the Web Resource provided below.

Web Resources for Step 10

Title: Got Gas?
URL:
http://www.tryscience.com/experiments/experiments_electrolysis_online.html
Annotation: Students should click “Try It Online” to view an interactive animation of this lab; then “Try It Offline” for directions for doing the experiment themselves.

Step: 11 Duration: 10 minutes / preferably on Day 2

Follow Up on Demonstration Labs

Return to observe the experiments begun at Step 3. For Demo Lab A, "How Much Oxygen is in the Air," carefully mark the level to which the water has risen inside the beaker. Then pick up the beaker and have a student measure the distance from the top to the mark. Record this as the numerator. Then, measure from the top of the beaker to the bottom, using the same units, and record that number as the denominator. This fraction represents the proportion of oxygen found in the air. (The beaker will appear to be about 1/5 filled with water, indicating that oxygen occupies about 20% of the air). Ask students to consider the following questions:

• What is the composition of Earth’s atmosphere? (The top four components are nitrogen (78%), free oxygen (21%), argon (0.9%) and carbon dioxide (0.05%).

• How has the composition of the earth’s atmosphere changed over the millennia? (Much of the lighter gases, such as helium and hydrogen, have escaped earth’s atmosphere. Cyanobacteria (blue-green algae) contributed almost all of the planet’s initial oxygen. Plants continue to generate earth’s oxygen). For teacher background information, see “Origins…of the Atmosphere”, linked below.

For Demo Lab B, "What Happens to Water Pulled up through Plant Roots?", allow the class to observe the zip-top bag with leaves inside. (Note that water droplets are evidence that transpiration or evaporation and condensation have taken place). Ask students to consider the following question and brainstorm possible answers:

• How much water vapor could be transpired by one acre of corn during a growing season? (It may not seem that water vapor from plants could enter the atmosphere in any significant quantities, since the process is invisible, but one acre of corn could transpire 400,000 gallons of water vapor in one season. If converted to liquid state, the water would cover one acre with a lake 15 inches deep. Source: Transpiration Web Resource linked below).

Web Resources for Step 11

Title: Transpiration
URL:

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/Transpiration.html
Annotation: Teacher background information. Online biology text with detailed information on transpiration with links to information on photosynthesis.

Title: Origins and Composition of the Atmosphere
URL: http://www.ux1.eiu.edu/~cfjps/1400/atmos_origin.html
Annotation: Teacher background information. Pie chart of atmospheric gases and diagram of atmosphere are useful background information for the teacher who may want to print copies on transparency film to show on an overhead projector.

Step: 12 Duration: 15 minutes

Debriefing Part 1: Big Ideas about Air

Refer to the chart pages on which the class' original predictions about air were recorded in Step 2. Check to see if everyone agrees with their earlier assumptions regarding the properties of air, and what it comprises. Using the Lab Report Answer Key for reference and the Web resources linked below, the teacher will lead a discussion about the lesson's Big Ideas about the properties of air. Ask students to summarize the results of each investigation in one sentence. Record these results on large chart paper. Possible responses may include the following:

• We can prove air exists because it has measurable properties (characteristics).
• Air has mass. Different gases have different masses.
• Air takes up space.
• Air presses against things. Air can be pushed or sucked into a space or compressed within a container.
• Air moves in response to temperature differences. Warm air expands and cool air contracts.
• Air can be compressed (squeezed into a smaller confined space, as pressure increases).
• Air moves in response to pressure differences, flowing from high to low pressure zones.
• Air has volume (and expands to fill a vacuum, although it may not fully expand otherwise).
• Gas molecules are always cycling through plants and animals, changing phases and getting involved in chemical reactions as they collide with other molecules in the atmosphere.
• Carbon dioxide is released into the atmosphere during plant respiration, decomposition, burning (combustion) and certain earth processes.
• Plants and blue-green algae release oxygen, CO_2 and water vapor into the atmosphere.

Step: 13 Duration: 10 minutes

Debriefing Part 2: Relating Properties of Air to Characteristics of Air Pollution

Ask students to consider this lesson's Big Ideas about the properties of air in terms of the implications for air pollution. Refer to the results recorded on chart pages in the previous step. Encourage brainstorming. Responses may include the following or other conclusions: • Since air moves in response to pressure and temperature differences, then air pollution can move to areas far from where it originates. People who are downwind of air pollution sources may be affected by the pollution as much as or more than people living near the source.

• Since different gases have different masses and lighter gases can move higher into the atmosphere, there may be different types of air pollution at different altitudes.

• Since warm air rises and expands and cool air sinks and contracts, polluted air could get trapped in an area when cool weather moves in.

Step: 14 Duration: Teacher Feedback

The Clean Air Campaign is pleased to provide standards-based air quality lesson plans for 4th through 8th grades. Please offer your feedback after implementing this lesson plan, because there is no substitute for real classroom experience. Send teacher name, school name and address, grade level, lesson name, comments or suggestions and the number of students who completed the lesson to: mail@cleanaircampaign.com. Each teacher who responds will receive a Clean Air Campaign goody bag as a 'thank you.'

Materials and Equipment

Please see the Materials List attached at Step 1

Total Duration

3 to 3 1/2 hours (depending on whether 6 or 8 lab stations are set up) over two or more days.

Technology Connection

Internet-connected computers will be used by students to view interactive Web sites related to the lab investigations at Steps 6, 8 and 10. In addition, the teacher will use Web resources for background information and may order supplies online.