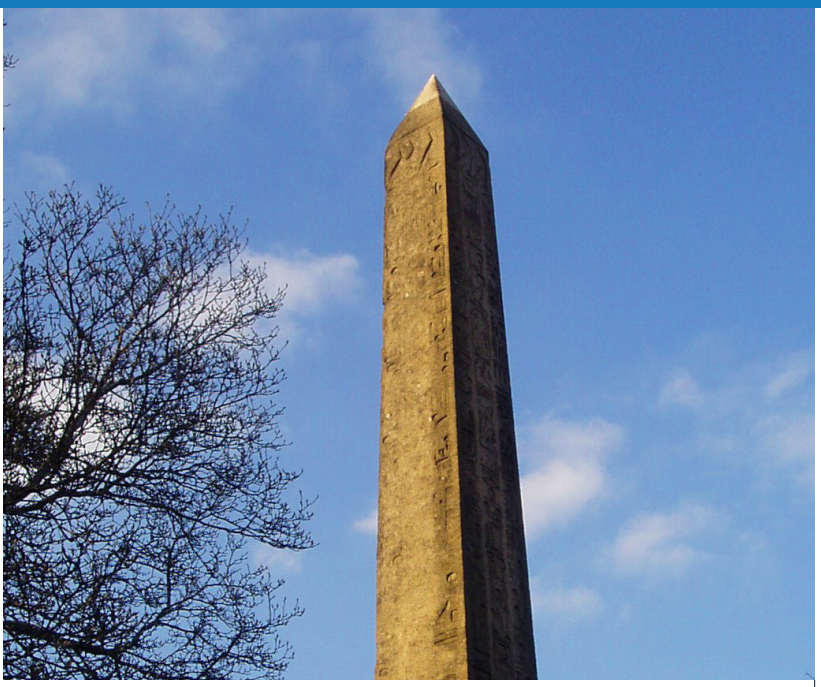


Acid Rain Drops Keep Falling on My Head

Investigating Acid Rain

MATERIALS AND RESOUCES

EACH GROUP

aprons
beaker, 100 mL
goggles
paper towels
6 pipettes, thin stem
hydrochloric acid, 1 *M*
plate, 24-well
potassium nitrite, solid
sodium bisulfite, solid
Universal Indicator
baking soda
water, distilled

ABOUT THIS LESSON

In this lesson students will be able to describe how CO_2, NO_2, and SO_2 gases cause acid rain by forming the following acids in the atmosphere: carbonic acid (H_2CO_3), nitrous acid (HNO_2), nitric acid (HNO_3), and sulfurous acid (H_2SO_3). It may be taught while studying the atmosphere, environmental issues, or even when teaching acid-base reactions and chemical changes.

OBJECTIVES

Students will:

- Describe the pH changes caused when the gases CO_2, SO_2, and NO_2 act as condensation sites in the atmosphere
- Calculate the change in pH caused by each of the three gases

LEVEL

Environmental Science

TEACHER PAGES

COMMON CORE STATE STANDARDS

(LITERACY) RST.6-8.1

Cite specific textual evidence to support analysis of science and technical texts.

(LITERACY) RST.6-8.3

Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

(LITERACY) WHST.6-8.1

Write arguments focused on discipline-specific content.

(MATH) 7.NS.A

Apply and extend previous understandings of operations with fractions.

(MATH) 7.EE.B

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

NEXT GENERATION SCIENCE STANDARDS

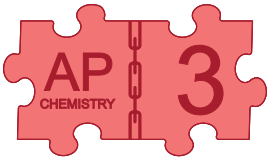
PLANNING/CARRYING OUT INVESTIGATIONS

CAUSE AND EFFECT

ESS3: HUMAN IMPACT

PS1: MATTER

CONNECTIONS TO OTHER AP* COURSES



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ASSESSMENTS

The following types of assessments are embedded in this lesson:

- Assessment of prior knowledge
- Formative assessment discussions during activity

The following assessments are located on the website

- 2009 8th grade Posttest, Free Response Question 1

TEACHER PAGES

TEACHING SUGGESTIONS

Investigating acid rain allows students to see how different gases added to the atmosphere might change the pH of rain. It may be taught while studying the atmosphere, environmental issues, or even when teaching acid-base reactions and chemical changes.

Students are using thin-stem disposable pipettes. These are extremely cheap and easy to use. To perform this lab, students must make four pipettes with a narrower stem to insert one pipette into another. You can easily do this by holding the pipette in the palm of your hand and gently stretching the stem of the pipette until it stretches into a uniform narrow diameter (Figure A).

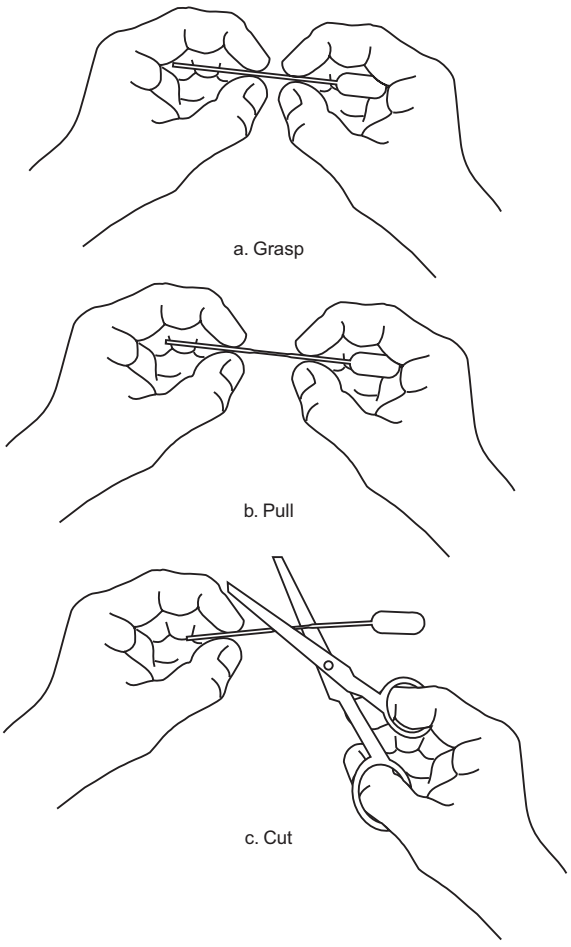

Figure A.

Cut the stem of the pipette so that there is 3 cm of narrow stem. Each group will need three small-opening pipettes for gas collectors and one for HCl. To make the wide-opening pipettes, cut off the stem at the junction to the bulb. This should make it easier to draw up small amounts of the solids. Each group will need three wide-opening pipettes. Have the students label the pipettes with a fine-tip marker. They can also use a piece of masking tape to create a label.

In your pre-lab discussion, you will need to discuss the gases produced by the reactions of $NaHCO_3(s)$, $KNO_2(s)$, and $NaHSO_3(s)$ with HCl. Also, be sure to show students how to use the color of the universal indicator solution to determine the pH of a solution. A brief review discussing the range of the pH scale may also be necessary.

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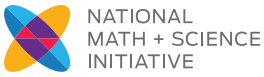

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NATIONAL MATH + SCIENCE INITIATIVE

Acid Rain Drops Keep Falling on My Head

Investigating Acid Rain

MATERIALS

aprons
beaker, 100 mL
goggles
paper towels
6 pipettes, thin stem
hydrochloric acid, 1 M
plate, 24-well
potassium nitrite, solid
sodium bisulfite, solid
Universal Indicator
baking soda
water, distilled

Acid rain is a serious problem in many parts of the United States. Any form of precipitation with increased levels of H^+ ions (lower than a pH of 5.7) is considered acid rain. Acid rain poses a threat to the natural environment as well as many human-made structures. Acidification of lakes, damage to trees and disruption of lotic ecosystems are a few of the impacts acid rain has on the environment. Acid rain also accelerates the decay of buildings, statues and monuments constructed of marble or limestone. It is the result of chemical reactions that take place in the atmosphere. While natural sources contribute to acid rain formation, the burning of fossil fuels also generates pollution that leads to acid rain. The three reactions below represent different forms of acid rain and describe their sources.

Carbonic acid is produced when carbon dioxide gas dissolves into rain droplets of unpolluted air:

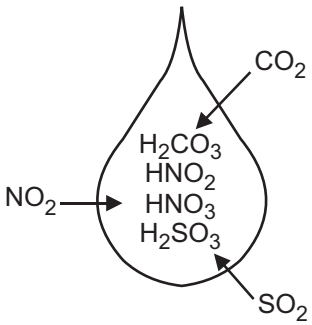
$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$

Nitrous acid and **nitric acid** result from a common air pollutant, nitrogen dioxide (NO_2). Most nitrogen dioxide in our atmosphere is produced from automobiles. Nitrogen dioxide gas dissolves into raindrops and forms nitrous and nitric acid:

$$2\ NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + HNO_3(aq)$$

Sulfurous acid is produced from another air pollutant, sulfur dioxide (SO_2). Most sulfur dioxide gas in the atmosphere results from the burning of coal containing sulfur impurities. Sulfur dioxide dissolves into raindrops and forms sulfurous acid:

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$



In the following outlined procedure, you will first produce and collect the three gases listed here by reacting the solids with HCl. After collecting the gas produced, you will then bubble the gases through water, producing the acids found in acid rain. Using universal indicator, which changes colors to indicate pH, you will observe the pH change of the water sample.

PURPOSE

In this activity, you will describe the pH changes caused when the gases CO_2, SO_2, and NO_2 act as condensation sites in the atmosphere.

SAFETY ALERT!

- Students must wear aprons and goggles at all times.
- Potassium nitrite is a strong oxidizer and a fire and explosion risk if heated.
- Sodium bisulfite is a severe skin irritant as an aqueous solution and moderately toxic.

PROCEDURE

1. Predict which gas will cause the greatest change in pH. Record your prediction on your student answer page.
2. Obtain and put on your safety goggles and apron.
3. Obtain your lab setup consisting of one well plate containing three small-stem and three wide-opening disposable pipettes. The large-opening ones should be labeled for each solid: $NaHCO_3$, KNO_2, and $NaHSO_3$. The small-stem pipettes should be labeled for the gases: CO_2, NO_2, and SO_2. Always set the disposable pipettes with the stems pointing upward in your well plate.

CAUTION! *Avoid inhaling dust from the solids*

4. Take your large-opening pipettes to the dispensing area and obtain the solid substances. Squeeze the bulb of the pipette to expel all of the air, hold the opening in the solid, and then release the bulb. Some of the solid will be drawn into your pipette. Do this several times for each solid until you have enough of the solid to fill the curved end of the bulb (Figure 1).

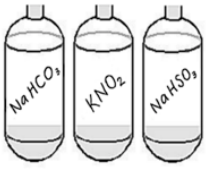


Figure 1. Wide-opening pipettes with solids

CAUTION! *HCl is a strong acid.*

5. Obtain a small-stem disposable pipette with 1.0 M HCl from your teacher. Gently hold the pipette with the stem pointing up so that the HCl drops do not escape. One at a time, insert the narrow stem of the HCl pipette into the large opening of the pipette containing the solid. Gently squeeze the HCl pipette to release about 20 drops of HCl into the solid (Figure 2).

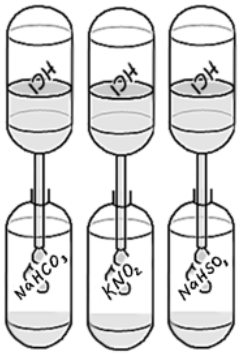


Figure 2. HCl being added to solids (Note: you will only have one pipette. Illustration shows all three steps.)

When finished, remove the HCl pipette and gently swirl the reaction pipette to mix them together. Leave the pipettes open-end up in your well plate.

The gases you have produced are denser than the air in the classroom, and will remain in the bulb of the pipette.

PROCEDURE (CONTINUED)

6. Obtain the small-stem pipette labeled "CO_2." Squeeze the air out of the bulb and collect the gas from the reaction pipette (labeled "$NaHCO_3$") by inserting the small-stem pipettes into the reaction pipette bulb (Figure 3).

   Slowly release the bulb so that the gas is drawn into the small-stem pipette. Place the CO_2 pipette stem-up in your well plate. Repeat this procedure for the remaining two gases and reaction pipettes.

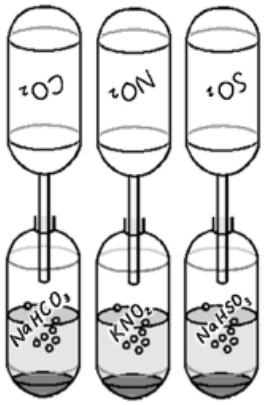


Figure 3. Gas collection

7. Fill three wells of your well plate halfway with distilled water. Add 10 drops of universal indicator solution to each water well. Compare the color of the solution to the color chart, and determine the initial pH of your water. The initial pH of the water should be neutral, or a pH of 7. If the well plate was contaminated and the initial pH is not close to 7, rinse the well plate (distilled water) and begin this step again. Record the initial pH in your data table.
8. Using the CO_2 gas pipette, insert the tip of the pipette into one of the wells filled with water and indicator solution. Slowly bubble the gas through the water. After 10 bubbles record the pH by observing the color change. Add an additional 10 bubbles (20 bubbles total) and record the pH. Repeat for a third time and record the final pH (30 bubbles total).
9. Repeat Step 8 for the remaining two gases and the remaining two water wells.
10. Dispose of your pipettes and clean up your lab area as instructed by your teacher.

PREDICTION

PRE-LAB

Identify which gas will be produced from each solid:

$NaHCO_3(s)$ → _____

$KNO_2(s)$ → _____

$NaHSO_3(s)$ → _____

DATA AND OBSERVATIONS

Table 1. pH of Dissolved Gases

Gas	Initial pH	After 10 Bubbles	After 20 Bubbles	Final pH	ΔpH
CO_2					
NO_2					
SO_2					

ANALYSIS

For each of the three gases, calculate the change in pH (ΔpH) by subtracting the final pH from the initial pH.

CONCLUSION

1. In this experiment, which gas (or gases) caused the smallest change in pH?

2. Which gas (or gases) caused the largest change in pH?

3. A coal-fired power plant prduces 10 million kWh of electricity each day. An input of 10,000 BTUs of heat is required to produce one kWh of electricity. Showing all steps in your calculation, determine the number of pounds of coal consumed by the power plant each day, assuming that one pound of coal yeilds 5,000 BTUs of heat.

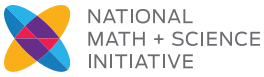
4. Coal from the western states of Montana and Wyoming is known to have a lower percentage of sulfur impurities than coal found in the eastern United States. How would burning low-sulfur coal lower the level of acidity in rainfall? Use specific information about gases and acids to answer the question.

5. Describe another method by which a coal-burning power plant can reduce sulfur emissions leading to a reduction in acid precipitation.

CONCLUSION (CONTINUED)

6. High temperatures in the automobile engine cause atmospheric nitrogen and oxygen gases to combine to form nitrogen oxides. Which two acids in acid rain result from the nitrogen oxides in automobile exhaust?

7. Catalytic converters are designed to reduce harmful nitrogen oxide emissions produced by automobiles. New catalytic converters are being designed to more effectively remove these emissions at a lower cost to the consumer. One new design promises to reduce the amount of nitrogen oxide emissions by 33%. How will that reduction change the impact that automobiles have to the environment? Support your answer with evidence from this experiment.



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