DOCUMENT RESUME

ED 234 990 SE 043 155

AUTHOR Barrow, Lloyd H.
TITLE Teacher's Resource Guide on Acidic Precipitation with Laboratory Activities.
INSTITUTION Maine Univ., Orono. Land and Water Resources Center.
SPONS AGENCY Department of the Interior, Washington, D.C.
PUB DATE Jun 83
NOTE 21p.
AVAILABLE FROM Land and Water Resources Center, Univ. of Maine at Orono, 11 Coburn Hall, Orono, ME 04469 ($1.00).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Energy; Environmental Education; *Geology; *Laboratory Procedures; *Meteorology; *Physical Environment; Resource Materials; Science Activities; Science Education; *Science Experiments; Secondary Education; *Secondary School Science
IDENTIFIERS *Acid Rain; pH

ABSTRACT

The purpose of this teacher's resource guide is to help science teachers incorporate the topic of acidic precipitation into their curricula. A survey of recent junior high school science textbooks found a maximum of one paragraph devoted to the subject; in addition, none of these books had any related laboratory activities. It was on the basis of this near void that this manual was developed. The guide includes introductory material designed to give an overview of causes and effects of acidic precipitation, its relation to energy production, and some possible ways of reducing or eliminating it. In addition, six laboratory activities (independent of one another) are included. These investigations are appropriate for students utilizing concrete operational patterns. Some are modifications of activities published by the Acid Precipitation Awareness Project. The guide also references several additional resources for teachers and students who wish to pursue the topic further. In addition, instructions are provided for preparing acid rain (using solutions prepared from nitric or sulfuric acids) should this be necessary to complete the investigations. (JN)

# TEACHER'S RESOURCE GUIDE
# ON
# ACIDIC PRECIPITATION
# WITH
# LABORATORY ACTIVITIES

DEVELOPED BY
LLOYD H. BARROW, PH.D.
COLLEGE OF EDUCATION



UMO LAND AND WATER RESOURCES CENTER
UNIVERSITY OF MAINE AT ORONO

# TEACHER'S RESOURCE GUIDE

# ON

# ACIDIC PRECIPITATION

# WITH

# LABORATORY ACTIVITIES

DEVELOPED BY

LLOYD H. BARROW, PH.D.
ASSOCIATE PROFESSOR OF SCIENCE EDUCATION
UNIVERSITY OF MAINE AT ORONO
ORONO, MAINE 04469

PUBLISHED JUNE 1983

The research on which this report is based was financed in part by the U.S. Department of the Interior, as authorized by the Water Research and Development Act of 1978 (P.L. 95-467).

TABLE OF CONTENTS



4

ACKNOWLEDGEMENTS

Many individuals have contributed to the development of this teacher's resource guide with laboratory activities. Specifically I want to recognize Paul Uttormark, Director of the UMO Land and Water Resources Center, Chris Cronan, coordinator of acidic precipitation research at UMO, Steven Norton, UMO Geological Sciences Department Chairman, for identifying the need, and other researchers I consulted with. I also wish to recognize Betty Bitner for her editorial assistance of the activities, Susan Landry for editorial assistance of the packet, and Barbara Corley and other secretaries for typing the manuscript.

Lloyd H. Barrow
March 1983

## NOTES TO TEACHERS

The purpose of this teacher's resource guide is to help science teachers incorporate the topic of acidic precipitation into their curricula. A survey of recent junior high school science textbooks found a maximum of one paragraph devoted to acidic precipitation. It was on the basis of this near void that this guide was developed. None of these textbooks had a laboratory investigation related to acidic precipitation.

The laboratory investigations are independent of one another. All investigations are appropriate for students utilizing concrete operational thought patterns. It is highly recommended that the two investigations "What's My pH?" and "Model pH" be utilized prior to others. Some of the investigations are modifications of activities published by the Acid Precipitation Awareness Project.

If teachers desire additional resources, the author recommends several sources. First, the Acid Rain Education Materials (Grades 7-12) from the Acid Precipitation Awareness Project, Independent School District #197, 1037 Bidwell Street, West Saint Paul, Minnesota 55118. The Project has developed interdisciplinary packets of classroom activities, overhead transparencies, and a bibliography; for availability and costs contact the Acid Precipitation Awareness office.

A second source is the Acid Rain Twinning Project, National Survival Institute, 229 College Street, 3rd Floor, Toronto, Ontario M5T 1R4. By having students participate in acid precipitation data collection you will receive a free packet. This packet contains pertinent information about this North American problem, facts for students, and extensive resources. This packet can be ordered for $5.00.

Another useful resource is the April/May 1983 issue of The American Biology Teacher. The entire issue focuses on Acid Rain. A single copy is available from NABT, 11250 Roger Bacon Drive, Reston, Virginia 22090. The cost of this issue is $4. This issue has several background articles and reviews, and seven high school biology laboratory activities.

With the rapidly changing status of acidic precipitation, both scientific and political, teachers need to utilize current resources such as newspapers, Time, Science News, etc. The inclusion of acidic precipitation in the curriculum helps to prepare the student to deal with a problem of the 1980's.

If you have any students interested in doing an acidic precipitation science project, the book Nuts & Bolts: A Matter of Fact Guide to Science Fair Projects, written by Barry A. Van Deman and Ed McDonald, is a good reference. This helpful book is available from the Science Mans Press, Harwood Heights, Illinois.

If you need to manufacture some acid rain, the following two recipes can be used.

1. Solutions using nitric acid. (NOTE: Be sure that these solutions are thoroughly mixed and that the pH of each is stable before they are used.)

A. pH = 6.5 ml concentrated $HNO_3$ per liter of solution. This solution of nitric acid and spring water may be used as a stock solution. It is a 0.1 M solution.
B. pH 2 = 2 ml of 0.1 M solution (pH 1) + 198 ml spring water, creating a 0.01 M solution.
C. pH 3 = 2 ml of 0.01 M solution (pH 2) + 198 ml spring water, creating a 0.001 M solution.
D. pH 4 = 2 ml of 0.001 M solution (pH 3) + 198 ml spring water, creating a 0.0001 M solution.
E. pH 5 = 2 ml of 0.0001 M solution (pH 4) + 198 ml spring water, creating a 0.00001 M solution.
F. pH 6 = 2 ml of 0.00001 M solution (pH 5) + 198 ml spring water, creating a 0.000001 M solution. (Plain spring water, which is close to pH 6, may be substituted.)

2. Solutions using sulfuric acid. The following pH solutions of $H_2SO_4$ may be used in place of the $HNO_3$ solutions. (NOTE: The pH of the stock solutions must be stable before they are used. As you add drops of $H_2SO_4$ be sure the solution is thoroughly stirred and that you measure the pH carefully. The number of drops recommended for each solution is approximate, so it is important that you take several pH measurements for each solution.)

A. 500 ml of spring water $\simeq$ pH 6
B. 500 ml of spring water + approximately 5 drops of 10% $H_2SO_4$ $\simeq$ pH 5
C. 500 ml of spring water + approximately 15 drops of 10% $H_2SO_4$ $\simeq$ pH 4
D. 500 ml of spring water + approximately 25 drops of 10% $H_2SO_4$ $\simeq$ pH 3
E. 500 ml of spring water + approximately 30 drops of 10% $H_2SO_4$ $\simeq$ pH 2
F. 500 ml of spring water + approximately 35 drops of 10% $H_2SO_4$ $\simeq$ pH 1

## INTRODUCTION

What is acidic precipitation? Acidic precipitation includes acid rain, acid snow, acid sleet, acid hail, acid fog and dry pollutants which form acid when they encounter moisture. All of these forms of precipitation are naturally acidic. This is due to the carbon dioxide in the atmosphere which combines with moisture to form a weak solution of carbonic acid.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Normally, rain tends to be acidic. Generally, rain has a pH of 5.6-5.7. Any precipitation that has a pH value of less than 5.6 is considered to be acidic. For example, one 1978 rain storm in Wheeling, West Virginia had a pH of less than 2.0. This storm was 5,000 times more acidic than normal rain. It was more acidic than the vinegar we use at home. Other atmospheric substances such as from volcanic eruptions, forest fires, biological decay in swamps, etc. add material to the atmosphere that results in acidic precipitation. However, the majority of the increase in acidic precipitation is due to industrial air pollution.

Degree of acidity is expressed by the pH scale. The pH scale is based on the relative concentration of hydrogen ions in a solution. On the pH scale the highest level of acidity has a value of zero, while the highest degree of alkalinity is 14. The neutral value is 7, for example distilled water. The pH scale is logarithmic; therefore, a pH of 4 is ten times more acidic than a pH of 5. Also, a pH of 11 is ten times more alkaline than a pH of 10. Buffering is the capability to neutralize acid. Airborne alkaline particles and many soils act as buffers of acidic precipitation.

## CAUSES OF ACIDIC PRECIPITATION

Oxides of sulfur and nitrogen that combine with water vapor and fall to earth are called acidic precipitation. The precursors are sulfur oxides ($SO_x$) and nitrogen oxides ($NO_x$). These gases enter the atmosphere primarily from fossil fuel combustion in power generating plants, industry, and internal combustion engines (i.e. cars, trucks). In the atmosphere, $SO_x$ is transformed into sulfates and $NO_x$ is transformed into nitrates. The sulfates when they combine with moisture in the air form sulfuric acid.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

The nitrates also combine with moisture in the atmosphere, to form nitric acid.

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

Once these acids are formed, they are removed from the atmosphere by rain, snow, or other precipitation. Consequently, the vast majority of acidic precipitation is due to $SO_x$ and $NO_x$. In the United States, there are 29.6 million tons of $SO_x$ emitted annually and 22.3 million tons of emissions of $NO_x$. The majority of these emissions come from the high-energy-demand industries of the Ohio River Valley.

Both natural and human causes are responsible for precipitation being acidic. All plants and animals release carbon dioxide as they breathe. Once organisms die and decompose, carbon dioxide is released, thereby forming carbonic acid. Sea spray from oceans also releases elements into the atmosphere, creating an acidic environment. Sulfur dioxide is naturally added to the environment from volcanoes, hot springs, wetlands, and natural gases. Nitrogen oxides are added to the atmosphere by lightning.

People have accelerated the acidic precipitation problem. As humans have increased industrialization, the acidic precipitation problem has been aggravated. The burning of fossil fuels, especially coal, in the production of electricity has added vast quantities of $SO_x$ into the atmosphere. For example, a 1,000 megawatt power plant burning 2,500,000 tons of high sulfur coal per year emits 23,000 tons of sulfur pollution and 21,000 tons of nitrogen pollution annually. If the same plant were fueled by natural gas, it would produce about 16 tons of sulfur pollution and 20,000 tons of nitrogen pollution. Heavy industry such as the smelting of ores and refining of petroleum products results in sulfur emissions. Paper, flour, and pulp mills produce hydrochloric acid, while steel, aluminum, fertilizer, and ore-smelting plants produce hydrofluoric acid—thereby continuing the environmental devastation of planet Earth.

## EFFECTS OF ACIDIC PRECIPITATION UPON THE ENVIRONMENT

All organisms are interdependent with one another and their environment. This interdependence has existed throughout the evolutionary process and still continues today. Food chains are easily disrupted when an organism is added or removed in the system. The Adirondack Mountains of New York, once a great fishing area, have been influenced by acidic precipitation. In the 1950's, the trout in the Adirondacks started to disappear. The acidification of the lakes was the cause of the decreased fish population. The remainder of this section is divided into three sections— aquatic, terrestrial, and human. In each of these sections, information is presented about how lower pH influences these ecosystems.

### AQUATIC:

The pH of a healthy freshwater lake is typically between 7.5 and 8.0. When there are changes in pH from 8.0 to 6.0, the composition of the food web may change and put additional stress on the competing organisms.

| | |
|---|---|
| pH 7.0 | Level of available calcium in the water declines. Eggs of several species of salamander fail to hatch due to low calcium level. |
| pH 6.6 | Snails begin to die. |
| pH 6.0 | No tadpoles or shrimp are found, and eggs of other salamander species fail to hatch. |
| pH 5.9 | Aluminum toxicity damages the fishes' gills; this can result in their death. |

| | |
|---|---|
| pH 4.5-6.0 | Number and diversity of species decrease rapidly. Bacterial decomposers at the bottom of the lake die. Plankton starts dying out. Decreased calcium influences the gills of smallmouth bass and trout and prevents egg production in walleyes. Toxic metals (aluminum, mercury, lead, calcium, tin, beryllium, and nickel) are released from sediments or leached from nearby soils. Mercury is converted to monomethyl mercury and absorbed by fish. |
| 4.5-5.5 | Acidophilic mosses, fungi, and filamentous algae have nearly choked out the other aquatic plants. Northern pike, suckers, and perch die out. Other fish eggs are unable to survive in the acidic water. Mature fish die from lack of food, gill damage, or toxicity. Sphagnum moss becomes the dominant aquatic plant because of acidity. |
| Below 4.5 | All fish are dead. The majority of the frogs and insects have died. Surface-living insects (i.e. backswimmers, waterboatmen, and water striders) can tolerate the acidity and flourish because of the lack of predators. Lake is clear and blue because protists have died. Sphagnum and algal-fungi growths on the lake bottom form a tight mat that prevents the release of nutrients from the sediments. |

TERRESTRIAL:

The effects of acidic precipitation on plants are not as well understood as effects on the aquatic environment. Studies in North Carolina found that acidic precipitation damages leaves' waxy surface, interferes with transpiration and gas exchange, poisons plants via their transport systems, which results in a lower photosynthesis rate, destroys root hairs, and decreases germination percentage. Plants' optimum growing conditions vary with type. For example:

| Plant | Optimum pH |
|---|---|
| alfalfa | 6.0-7.0 |
| beans | 6.0-7.0 |
| begonia | 6.0-8.0 |
| carrot | 5.5-6.5 |
| coleus | 6.0-8.0 |
| dandelion | 6.0-8.0 |
| lettuce | 6.0-7.0 |
| lima beans | 5.5-6.5 |
| maple | 5.0-6.0 |
| oak | 6.0-7.0 |
| parsley | 5.0-7.0 |
| pine | 5.0-6.0 |
| potato | 5.0-7.0 |
| radish | 6.0-8.0 |
| spruce | 5.0-6.0 |

In addition to influencing plant growth, acidic precipitation increases the leaching of certain minerals from the soil. Specifically, calcium, magnesium, potassium, phosphorus, and sodium are leached and transported into the aquatic environment, influencing organisms there. Also, acidic precipitation causes toxic metals such as aluminum, manganese, iron, mercury, cadmium, and lead to be more soluble and more easily absorbed by plant roots. Acidic precipitation also kills the microorganisms that decompose plant litter. Lower pH also results in reduced nitrogen-fixing bacteria.

Some plant growth rates are improved by acidic precipitation. A dilute nitric acid precipitation can facilitate a few plants by adding nitrogen to the soil. This short-term fertilizing action tends to be dependent upon soil quality. Dilute sulfuric acid precipitation can promote plant growth when the soil is deficient in the trace element sulfur. However, too much nitrogen and/or sulfur can be harmful to plants.

HUMAN:

Acidic precipitation influences humans through aquatic and terrestrial ecosystems. Large quantities of mercury, aluminum and/or lead that were absorbed by plants and aquatic organisms are harmful to humans who eat them. These metals accumulate in plants and animals. When people eat the affected organisms, these metals are retained in their bodies. They accumulate in people just as in other organisms. For example, pregnant and lactating women are advised to avoid eating freshwater fish and others more than once a week. High metal levels in drinking water can cause vomiting and metal poisoning. $SO_x$ and $NO_x$ can cause or lead to severe respiratory difficulties such as bronchitis and emphysema. The long-term health effects are unknown at this time.

Acidic precipitation also affects buildings. Along with other air pollutants, acidic precipitation can wear away the surface layer of buildings, statues, and monuments (particularly those made of limestone, marble, and sandstone). In addition, the pH is low enough in some precipitation to remove paint from buildings and vehicles. It is theorized that as acidic water passes through plumbing, copper and lead can be leached from pipes into drinking water. However, the most significant effect will be economic— i.e. the cost of restoring ecosystems to their pre-acidic precipitation states.

## METEOROLOGICAL EFFECTS

In 1881, Norwegian scientist W. C. Brogger speculated that pollution generated in Great Britain was the source of polluted snow in Norway. Weather has no national boundaires. Consequently, the pollution generated in one area can be deposited in another area. If it weren't for large-scale weather systems, acidic precipitation would be a local problem. An example of large-scale movements of air is a cold air front from the Arctic. As a weather system moves it picks up local air pollution and transports it long distances.

High pressure systems enter the Midwest from Canada from May through October. Sometimes these fronts become stationary for 2-3 weeks before being blown out to sea. The air masses travel in wide clockwise circles with diameters of several hundred miles. Consequently, $SO_x$ and other pollutants from the industrial Ohio River Valley are carried east and north to New England and

Canada by the prevailing northeasterly winds. As the air system progresses towards the Atlantic Ocean, acidic precipitation falls on the Great Lakes area, Canada, and New England. The slower moving the air front, the longer the time available for $SO_x$ and $NO_x$ to be converted to sulfuric and nitric acid.

Relative humidity of an area influences the severity of acidic precipitation. The drier the climate, e.g. in the Western United States, the more airborne dust there is; this dust is alkaline and tends to neutralize atmospheric acidity. Consequently, acidic precipitation is not as severe in the Western United States as it is elsewhere. However, along the Eastern part of the United States there is less alkaline dust in the air, so the acidic precipitation is more severe.

There are additional meteorological concerns. For example, the buildup of acids in fallen snow can have disastrous effects when the snow melts and the acidic runoff flows into streams where fish are spawning or into soils where seeds are germinating. Also, acidic precipitation occurs more commonly when the prevailing winds are blowing from the direction of major $SO_x$ and $NO_x$ sources.

## GEOLOGICAL INTERACTIONS

Some areas of the world seem more sensitive to acidic precipitation than do others. This is because these areas have less buffering capacity and greater sensitivity; they do not neutralize as much precipitation as less sensitive areas. As rocks are weathered they release ions. Weathering is the breaking down of rock by natural forces such as rain, wind, running water, plant roots, etc. Igneous and metamorphic rocks are more resistant to weathering than sedimentary rocks: consequently, they release few ions to the surrounding soils.

In addition to type of bedrock influencing buffering capacity, there are several other factors. The mineral content of the overburden, the depth of surrounding soils in the watershed, glacier percolation rates, and the slope of the land also influence an area's buffering capacity. In addition, areas of glacial action influence the buffering capacity. If the glacial area has been one of soil removal, the remaining thin layer of soil and its ecosystem are vulnerable to acidic precipitation. Because these soils are thin and slightly acidic, they contain few calcium, magnesium, and carbonate ions. If these ions were present, they would buffer the soil against acidic precipitation.

## ENERGY AND ACIDIC PRECIPITATION

Prior to the Iran oil embargo of 1973, crude oil was selling for $3 per barrel. Today, the going rate is around $30 per barrel. As the cost of imported oil has increased, there has been a move toward the utilization of domestic energy resources. The United States' largest energy resource is coal. The current administration has recommended an increase in coal consumption. When burned, each ton of eastern United States coal results in the production of about 83 pounds of $SO_2$.

In the 1960's and 1970's, there was a tendency to construct tall smokestacks, some of them over 100 stories tall. These tall stacks did reduce the local air pollution problem, but now long-range transport of air pollutants (up to thousands of miles) is possible because pollutants from tall smokestacks remain in the atmosphere for several days.

Therefore, part of the acidic precipitation problem is closely linked to energy production, particularly the burning of fossil fuels.

## POSSIBLE SOLUTIONS FOR ACID PRECIPITATION

The solving of the acidic precipitation problem is not going to be simple or inexpensive. Some suggested methods follow.

1. Reducing $SO_x$ emissions

   A. Cleaner burning of fossil fuels— such as employing flue gas desulfurization, thereby reducing the $SO_x$ emissions by 80-90%

   B. Removing sulfur from coal before it is burned

   C. Burning less fossil fuel and utilizing renewable energy sources

   D. Replacing some solid coal with coal that has been gasified or liquified— this results in 90-95% reduction of $SO_x$ emissions (this is expensive)

   E. Requiring use of scrubbers, which can remove as much as 95% of the sulfur going up the stack

2. Modifying the Clean Air Act

   A. The 1977 Amendment required more stringent controls on electrical generating plants built since that year, but the great majority were built prior to 1977. The same 1977 requirements could be expanded to all plants built prior to 1977. This would be expensive.

   B. A revision of the Clean Air Act was being debated as this resource guide was written. Check on the modifications.

3. Reducing $NO_x$ emissions

   A. Use of catalytic converters on motor vehicles

   B. Development of more efficient vehicle emission control technology

   C. Greater energy conservation

   D. Car pooling, mass transit, and driving more efficient vehicles

E. Keeping automobiles properly tuned

4. Modifying acid lakes and/or their life

A. Adding lime to lakes will raise the pH, which will allow aquatic organisms to live in this environment. This is a very expensive process and is only a short-term solution because continuing acidic precipitation will lower the pH. This procedure will be beneficial only when a lake is only slightly acidic.

B. Develop aquatic organisms that can adapt and reproduce in low pH waters.

## SUMMARY

Acidic precipitation is one of the most recently identified and least understood environmental hazards. As the United States increases its use of coal for energy, the acidic precipitation problem is going to accelerate. Since Maine is a common exhaust line for the jet streams, the acidic precipitation problem will escalate logarithmically unless technological advances decrease $SO_x$ and $NO_x$ emissions. Maine will always be vulnerable to acidic precipitation because our soil and rock strata are slightly acidic. Maine with its abundant lakes and ponds is as susceptible to acidic precipitation as were the Adirondacks. Our forests have heavy metals leached from the soil, resulting in lower long-term timber yield. Laboratory studies have shown significant reduction in plant productivity in simulated acidic precipitation conditions.

All of the information contained in this teacher's resource guide is cause for concern about the future health and productivity of flora and fauna. It is hoped that the following cartoon will not be typical of Maine in the mid to late 1980's.


"... An acid rain?! ..."

Activity: What's my pH?

Materials: pH paper
pH color chart
baby food jars
tweezers
common household solutions such as orange juice, apple juice, 5 mg baking soda in 100 ml water, vinegar, distilled water, tap water, bleach, liquid detergent, ammonia, lemon juice, cranberry juice, milk of magnesia and soft drink
river water and acid rain/snow

Procedures:

1. A common measure of acidity is the pH scale. This scale ranges from 0 to 14. Pure water is neutral at pH 7. Solutions with lower values are acids; those with values higher than pH 7 are bases.
2. Using tweezers, dip a small piece of pH paper into the sample. Remove it.
3. Immediately compare the color of the pH paper with the color chart.
4. Record the pH value for the solution.
5. Using a fresh piece of pH paper each time, repeat the test for each sample.
6. Wash all baby food jars and rinse with distilled water before using again.
7. Make a chart with the solutions arranged from the lowest pH to the highest pH.
8. Test and record the pH of the acid rain/snow and river water.

Interpretations:

A. How do your team's pH values compare with those of at least two other teams?

B. Which of the household solutions was closest to the pH of the acid rain/snow?

C. For which solution was there the greatest variation in pH? What do you think is a cause for this variation?

Enrichment:

A. Compare the pH of rain water collected early in a storm or shower with that of a sample collected at the end of the storm.

B. Compare the pH measurements of stormwater from various areas of your community.

C. Using the newspaper's weather section, compare the acid rain values throughout the state.

Activity: Model pH

Materials for Team of 4: adding machine tape cut in 15 m lengths, metric ruler and red marking pen/pencil

Procedures:

1. Unroll the adding machine tape.
2. Measure 1 m from the right end of the tape. Draw a line across the tape and label it pH 7. This value is neutral.
3. On the left side of the line, measure 10 mm from the pH 7 line and draw another line. Label this line pH 6. This means that a liquid with a pH of 6 is 10 times more acidic than a liquid with a pH of 7.
4. On the left side of the pH 6 line, measure 10 times the distance from pH 7 to pH 6. How many cm will this be? Check your answer with your teacher before drawing the line. Label this line pH 5. (This is 10 times more acidic than pH 6.)
5. Continuing on the left side of pH 5, measure 10 times the distance from pH 6 to pH 5. This distance is how many cm? Label this line pH 4.
6. Continuing on the left side of the pH 4 line, measure 10 times the distance from pH 5 to pH 4. How many m will this be? Check your answer with your teacher before drawing and labeling the line pH 3.
7. In the part of your tape below pH 3, measure the distance from pH 3 to the end of the tape. Record your distance. Determine the pH value at the end of your tape. Remember that the pH values increase by 10. Your value can include a decimal. How many times more acidic is this value than pH 3?
8. Now go to the space above pH 7. To determine the location for pH 8, measure 1/10 of the distance from pH 7 to pH 6 (1/10 x 10 mm = 1 mm). Label this line pH 8. All pH values higher than 7 are bases.
9. pH 9 is 1/10 the value of pH 8. This value is .1 mm from pH 8.
10. On your tape, label the following solutions with corresponding pH:

| | |
|---|---|
| Distilled water | 7.0 |
| Milk | 6.6 |
| Tomato Juice | 4.2 |
| Normal rain | 5.6 |

11. All rain lower than pH 5.6 is considered acid rain. On your tape, draw a red line for all acid rain possible.

Interpretations:

A. According to your tape, how much more acidic is a solution of pH 4 than a solution of pH 5? pH 6? pH 7?

B. According to your tape, how much less acidic is a solution of pH 4 than a solution of pH 3? ph2?

C. On your tape, the distance from pH 5.4 to pH 5 is what length?

D. Write a summary statement about lower pH values and acid content.

Activity: pH and Lemonade

Materials for Team of 4:
- lemonade concentrate, thawed
- distilled water
- pH paper
- pH color chart
- graduated cylinder
- beaker or large jar
- baby food jars

Procedures:

1. Using distilled water, mix the lemonade as directed on the package.
2. Determine the pH of the lemonade. Record this value. Determine and record the pH of distilled water.
3. Measure 50 ml of the lemonade; add 50 ml of distilled water. Predict the pH of this solution. Test your prediction.
4. Measure 25 ml of the lemonade; add 75 ml of distilled water. Predict and test the pH of this solution.
5. Measure 10 ml of lemonade; add 90 ml of distilled water. Test and record the pH of this solution. Label this solution A.
6. Take 10 ml of solution A and a different amount of distilled water of your own choosing. Predict and test the pH of your solution. Make 3 more combinations of distilled water. Start each trial with 10 ml of solution A. Test and record the pH. Graph the results. Compare your results with at least 2 other teams.
7. After completing your testing, you may drink your lemonade solutions.

Interpretations:

A. How does adding water influence pH?

B. Predictions do not have to be exactly correct to be good. Did your predictions get better with practice? Why?

C. Why do you think some lemonade tastes better than others?

Enrichment:

Write a poem or advertisement about pH and lemonade.

Activity: pH Recipe

Materials: jars
solution A
graduated cylinder
pH paper
distilled water

Procedures:

1. Your teacher will give you a solution labeled A. This solution was made by adding 5.5 ml of concentrated sulfuric acid to 94.5 ml of distilled water. Test and record the pH of solution A.
2. Add 10 ml of solution A to 90 ml of distilled water. Always add the acid solution to the distilled water. Label this solution B. Test and record the pH of solution B. Have your teacher check these values.
3. Add 10 ml of solution B to 90 ml of distilled water. Label this solution C. Test and record the pH of solution C.
4. Add 50 ml of solution C to 50 ml of distilled water. Test and record the pH.
5. Add 10 ml of solution C to 90 ml of distilled water. Test and record the pH.

Interpretations:

A. How does adding water influence pH?

B. Which of the four solutions was most acidic? Why?

C. Write a summary statement about pH value and acid content.

Enrichment:

A. Pick a quantity of solution C and add distilled water to equal 100 ml. Predict the pH. Test and record the pH.

B. Draw a cartoon sequence showing how acid rain influences our lives.

C. Write a haiku about acid rain.

Activity: Influence of Acid Rain on Different Rocks

Materials: 3 beakers either 400 ml or larger
crushed limestone
crushed granite
balance
acid rain/snow
pH paper

Procedures:

1. Label the beakers 1, 2, and 3.
2. Put 300 ml of acid rain/snow in beaker 1. Test the pH of the acid rain. Record the pH.
3. Put 300 ml of acid rain/snow and 100 g of crushed limestone in beaker 2. Test and record its pH.
4. Put 300 ml of acid rain and 100 g of crushed granite in beaker 3. Test and record its pH.
5. Predict what the pH will be in each beaker for 5 consecutive days. Daily, test and record the pH for each beaker.

Interpretations:

A. Which beaker had the lowest pH? Highest pH?

B. Which beaker was the most acidic? Least acidic?

C. Assume that each beaker was a lake basin: which lake basin was the least affected by the acid rain? Why?

D. Which lake basin type of rock would be best in an environment where there is acid rain? Why?

Enrichment:

Write a 30-second television report that explains how the type of rock influences the pH of water.

Activity: Influence of Acid Rain on Plant Cuttings

Materials: vermiculite or soil
jar/cup
leaves of coleus, begonia, or African violet
distilled water, tap water, and acid rain/snow
graduated cylinder, 30 cm ruler

Procedures:

1. Determine and record the pH of the distilled water, tap water, and acid rain/snow. Keep your water container covered and labeled.
2. Label the jar/cup according to the type of water used.
3. Pot three leaves of the provided plant. Make sure that you use the same type and amount of soil/vermiculite. Place all three containers so that the leaves are at the same temperature and receive equal amounts of sunlight.
4. Keep a daily record of the amount of water added to each plant.
5. Check for the growth of roots on each leaf. Write a description or draw a picture of the roots growing. Measure the length in millimeters.

Interpretations:

A. Of the distilled water, tap water, and acid rain which one was the control?

B. Which pH grew the roots fastest?

C. Which pH slowed the growth rate?

D. Based upon your experiment, what pH range would you recommend for starting plant cuttings? Why?

E. How do you think acid rain influences plants?

Enrichment:

Hypothesize whether pH of 3, 4, 5, 6, 8, 9, or 10 will cause roots to grow the fastest. Design an experiment to test your hypothesis. Share your design with your teacher.