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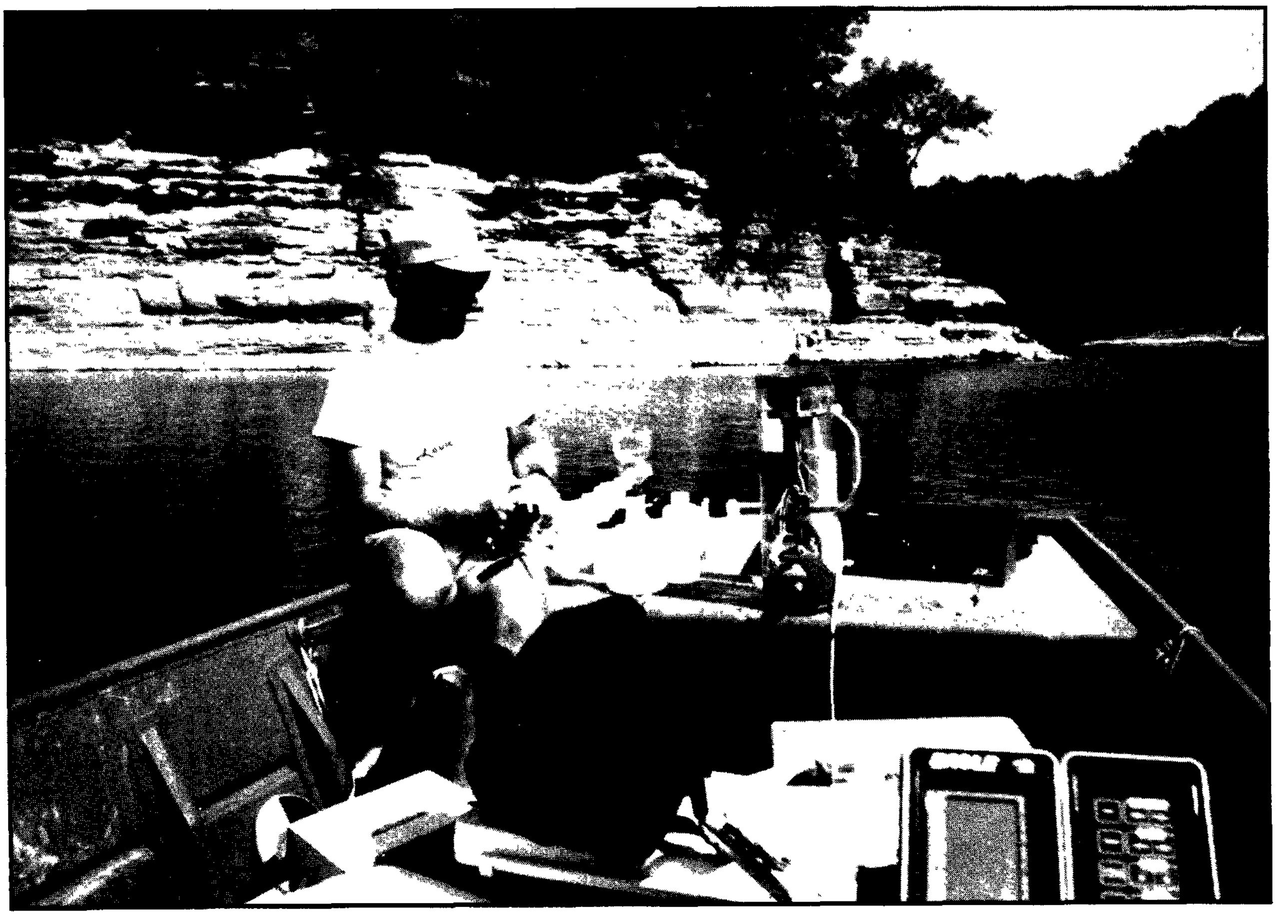
EPA

Acid Rain:
A Student's First Sourcebook



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Cover: Hydrologist testing water samples from a test lake (photo courtesy of International Science and Technology, Inc.)

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PURPOSE

The primary goal of the U. S. Environmental Protection Agency (EPA) is to protect human health and the environment. One of the ways in which EPA tries to achieve that goal is to educate the public on matters of local and national concern. Acid rain affects both the health of humans and our environment and is an issue with which the EPA is actively involved. EPA provides information on research, regulation, and other issues associated with acid rain. Because acid rain is of national and international concern, many other government organizations are also responsible for working on this problem.

EPA frequently receives requests for information on acid rain from school systems, teachers, and individuals. Some seek suggestions for simple experiments to demonstrate concepts related to acid rain science. Others want information on the latest research and efforts to lessen the effects of acid rain. Still others want to know how citizens can become involved in helping to reduce the potential impact of acid rain. In response to these requests, EPA has developed this study guide. The purpose of the guide is to help students better understand the science, citizen action, and research issues that are part of the acid rain problem.

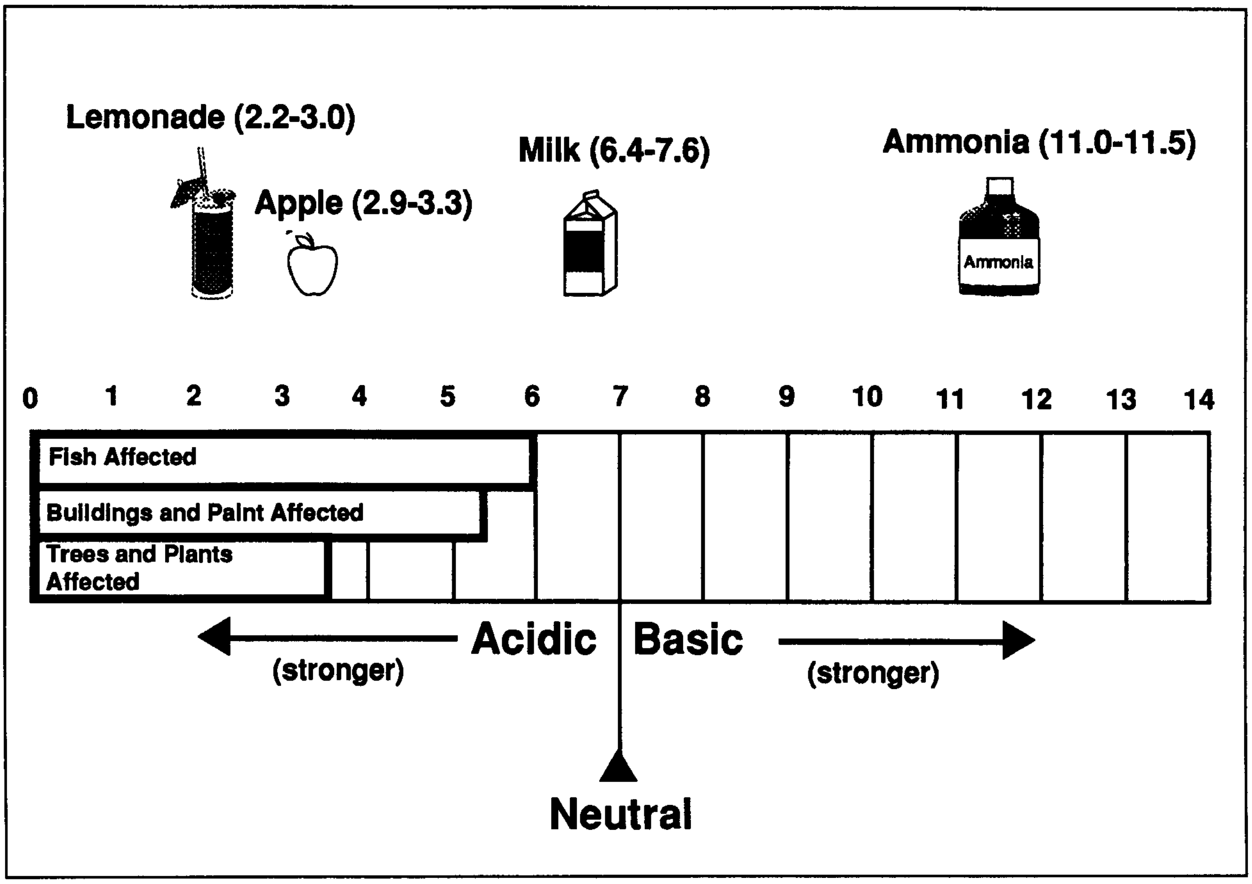
This book is for students in grades 4-8 and their teachers. After reading the concepts and definitions and doing some of the experiments and activities in the guide, we hope that they will have a better understanding of the acid rain problem and a greater interest in its resolution.

INTRODUCTION

Words that are explained in the glossary, which begins on page 55, are printed in **boldface** type the first time they appear.

Since the beginning of time, humans have learned to make use of many things in nature such as fire and electricity. From the early times through the Industrial Revolution to the Space Age, humans have produced inventions that use many of the earth's varied **ENERGY** resources to make living easier. In many cases the energy comes from burning **FOSSIL FUELS**—coal, oil, and natural gas.

Some of the inventions that make our lives easier are also causing **POLLUTION.** Pollution is the release of harmful substances into the **ENVIRONMENT**. One form of pollution is **ACID RAIN.** Acid rain can damage plants, animals, soil, water, building materials, and people. Scientists have discovered that burning fossil fuels creates acid rain through air pollution. People burn fossil fuels such as oil and coal to make electricity. Electricity heats and lights buildings and runs appliances such as televisions and video recorders. Fossil fuels power our cars, buses, and airplanes. The air pollution created when these fuels burn does not stay in the air forever. It can return to the earth as acid rain. And when it does, it may weaken the plant and animal life it contacts. Acid rain is only one form of pollution that results from burning fossil fuels. It is of particlar interest, however, because it can be transported over long distances. Scientists, engineers, and researchers are learning how to measure the amount and effects of pollution in the air, forests, water, and soil. They are inventing ways to reduce the amount of pollution that enters the environment and to prevent new damage in the future.



This diagram shows the pH scale. On top are some common items and their pH. A pH stronger than around 5 can harm buildings, metals, paint, and other materials. What pH level can harm fish? How about plants? Are these levels of acidity stronger or weaker than the level that affects materials? See the next page to learn more about pH.

OBSERVATIONS ABOUT ACIDITY

ACIDIC and **BASIC** are two extremes that describe **CHEMICALS**, just like hot and cold are two extremes that describe temperature. Mixing **ACIDS** and **BASES** can cancel out their extreme effects, much like mixing hot and cold water can even out the water temperature. A substance that is neither acidic nor basic is **NEUTRAL**. The **pH scale** measures how acidic or basic a substance is. The pH scale ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic. A pH greater than 7 is basic.

Pure water is neutral. But when chemicals are mixed with water, the mixture can become either acidic or basic. Examples of acid substances are vinegar and lemon juice. Laundry detergents and ammonia are examples of basic substances. Chemicals that are very basic or very acidic are **REACTIVE.** These chemicals can cause severe burns. Automobile battery acid is an acidic chemical that is reactive. Automobile batteries contain a stronger form of some of the same acid that is in acid rain. Household drain cleaners often contain lye, a very **ALKALINE** (another way to say basic) chemical that is reactive.

The pH Scale

The pH scale measures how basic or how acidic a substance is. Here are some facts about pH:

- The pH of a substance is a number that indicates how acidic or how basic the substance is.
- The values on a pH scale range from 0 to 14.
- A pH of 7 is neutral.
- A **SOLUTION** with a pH greater than 7 is basic.
- Each whole pH value above 7 is 10 times more alkaline than the next lower whole value. For example, pH 10 is10 times more alkaline than pH 9 and 100 times (10 times 10) more alkaline than pH 8.
- A solution with a pH less than 7 is acidic.
- Each whole pH value below 7 is 10 times more acidic than the next higher whole value. For example, pH 4 is ten times more acidic than pH 5 and 100 times (10 times 10) more acidic than pH 6.

Experiments on pH

The following are examples of experiments to demonstrate pH. Complete directions for these and other experiments are listed in the **Experiments** section beginning on page 25.

<u>Learning How to Use pH PAPER</u> Test the pH of distilled water (neutral) poured into a cup. Test after adding vinegar (an acid) and then again after adding baking soda (a base).

<u>Measuring pH of Common Substances</u>. Measure the pH of common household items such as fruits, beverages, and detergents.

<u>Making a Natural pH Indicator.</u> Boil red cabbage in water. The resulting liquid will change in color with the addition of acids and bases.

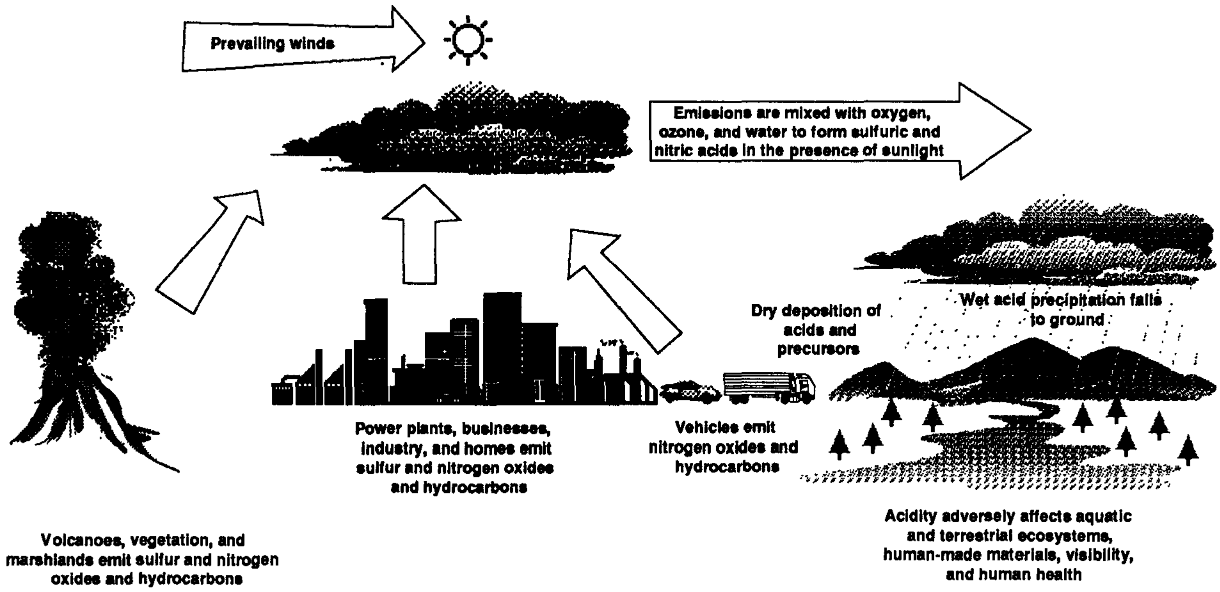
DEFINING ACID RAIN

Acid rain is rain that is more acidic than normal. Acid rain is a complicated problem. Caused by air pollution, acid rain's spread and damage involves weather, chemistry, soil, and the life cycles of plants and animals on the land and from acid rain in the water.

Air Pollution Creates Acid Rain

Scientists have discovered that air pollution from the burning of fossil fuels is the major cause of acid rain. Power plants and factories burn coal and oil. Power plants use that coal and oil to produce the electricity we need to heat and light our homes and to run our electric appliances. We also burn natural gas, coal, and oil to heat our homes. Cars, trucks, and airplanes use gasoline, another fossil fuel.

The smoke and fumes from burning fossil fuels rise into the **ATMOSPHERE** and combine with the moisture in the air to form acid rain. The main chemicals in air pollution that create acid rain are **SULFUR DIOXIDE** and **NITROGEN OXIDES**. Acid rain usually forms high in the clouds where sulfur dioxide and nitrogen oxides react with water, oxygen, and **OXIDANTS**. This forms a mild solution of **SULFURIC ACID** and **NITRIC ACID.** Sunlight increases the rate of most of these reactions. Rainwater, snow, fog, and other forms of **PRECIPITATION** containing those mild



Formation of Acid Rain

solutions of sulfuric and nitric acids fall to earth as acid rain.

Acid Precipitation

Water moves through every living plant and animal, streams, lakes, and oceans in the **HYDROLOGIC CYCLE.** In that cycle, water evaporates from the land and sea into the atmosphere. Water in the atmosphere then **CONDENSES** to form clouds. Clouds release the water back to the earth as rain, snow, or fog. When water droplets form and fall to the earth they pick up **PARTICLES** and chemicals that float in the air. Even clean, unpolluted air has some particles such as dust or pollen. Clean air also contains naturally occurring gases such as **CARBON DIOXIDE.** The interaction between the water droplets and the carbon dioxide in the atmosphere gives rain a pH of 5.6, making even clean rain slightly acidic. Other natural sources of acids and bases in the atmosphere may lower or raise the pH of unpolluted rain. However, when rain contains **POLLUTANTS,** especially sulfur dioxide and nitrogen oxides, the rain water can become very acidic.

Dry Deposition

Acid rain does not account for all of the acidity that falls back to earth from pollutants. About half of the acidity in the atmosphere falls back to earth through **DRY DEPOSITION** as gases and dry particles. The wind blows these acidic particles and gases onto buildings, cars, homes, and trees. In some instances, these gases and particles can eat away the things on which they settle. Dry deposited gases and particles are sometimes washed from trees and other surfaces by rainstorms. When that happens, the **RUNOFF** water adds those acids to the acid rain, making the combination more acidic than the falling rain alone. The combination of acid rain plus dry deposited acid is called acid deposition.

Acid Rain Is a Problem that Can Travel

The chemical reactions that change air pollution to acid rain can take from several hours to several days. Years ago, when smokestacks were only a few stories high, pollution from smokestacks usually stayed near the ground and settled on the land nearby. This caused unhealthy conditions for plants and animals near those smokestacks. To reduce this pollution, the government passed a law permitting the construction of very tall smokestacks. At that time, people thought that if the pollution were sent high into the air it would no longer be a problem. Scientists now know that this is incorrect. Sending pollution high into the sky increases the time that the pollution stays in the air. The longer the pollution is in the air, the greater are the chances that the pollutants will form acid rain. In addition, the wind can carry these pollutants for hundreds of miles before they become joined with water droplets to form acid rain. For that reason, acid rain can also be a problem in areas far from the polluting smokestacks. Dry deposition is usually more abundant near the cities and industrial areas where the pollutants are released.

Eruption of the Mt. St. Helens volcano in Washington State (photo courtesy of the U.S. Fish and Wildlife Service)

Natural Acids

There are also natural sources of acids such as volcanoes, natural geysers, and hot springs. Nature has developed ways of recycling these acids by absorbing and breaking them down. These natural acids contribute to only a small portion of the acidic rainfall in the world today. In small amounts, these acids actually help dissolve nutrients and minerals from the soil so that trees and other plants can use them for food. The large amounts of acids produced by human activities overload this natural acidity.

EFFECTS OF ACID RAIN ON FORESTS

Over the years, scientists, foresters, and others have watched some forests grow more slowly without knowing why. The trees in these forests do not grow as quickly as usual. Leaves and needles turn brown and fall off when they should be green and healthy.

Researchers suspect that acid rain may cause the slower growth of these forests. But acid rain is not the only cause of such conditions. Other air pollutants, insects, diseases, and drought are some other causes that harm plants. Also, some areas that receive acid rain show a lot of damage, while other areas that receive about the same amount of acid rain do not appear to be harmed at all. However, after many years of collecting information on the chemistry and biology of forests, researchers are beginning to understand how acid rain works on the forest soil, trees, and other plants.

Experiments on Acids in Soil

You can conduct experiments to demonstrate the effects of acid rain on forests and soils. Complete directions for these and other experiments are listed in the **EXPERIMENTS** section beginning on page 25.

Determining Soil pH Using a soil pH test kit, measure soil collected from several different locations such as a garden, wooded area, park, or meadow.

Looking at Soil Buffering Measure the pH of a liquid that has been filtered through a soil buffer. Pour an acidic liquid through. Measure the pH again and compare the results of the first and second tries.

Observing the Influence of Acid Rain on Plant Growth Compare the growth of plant cuttings raised in distilled water with that of plant cuttings raised in a water and vinegar mixture. Observe growth over several weeks.

Acid Rain on the Forest Floor

A spring shower in the forest washes leaves and falls through the trees to the forest floor below. Some of the water soaks into the soil. Some trickles over the ground and runs into a stream, river, or lake. That soil may **NEUTRALIZE** some or all of the acidity of the acid rainwater. This ability of the soil to resist pH change is called **BUFFERING CAPACITY**. A **BUFFER** resists changes in pH. Without buffering capacity, soil pH would change rapidly. Midwestern states like Nebraska and Indiana have soils that are well buffered. Places in the mountainous northeast, like New York's Adirondack Mountains, have soils that are less able to buffer acids. Since there are many natural sources of acids in forest soils, soils in these areas are more susceptible to effects from acid rain.

How Acid Rain Harms Trees

Acid rain does not usually kill trees directly. Instead, it is more likely to weaken the trees by damaging their leaves, limiting the nutrients available to them, or poisoning them with **TOXIC** substances slowly released from the soil.

Scientists believe that acidic water dissolves the **NUTRIENTS** and helpful minerals in the soil and then washes them away before the trees and other plants can use them to grow. At the same time, the acid rain causes the release of toxic substances such as aluminum into the soil. These are very harmful to trees and plants, even if contact is limited. Toxic substances also wash away in the runoff that carries the substances into streams, rivers, and lakes. Less of these toxic substances are released when the rainfall is cleaner.

Even if the soil is well buffered, there can be damage from acid rain. Forests in high mountain regions receive additional acid from the acidic clouds and fog that often surround them. These clouds and fog are often more acidic

Forest damage to which acid deposition may have been a contributing cause (photo courtesy of the National Acid Precipitation Assessment Program).

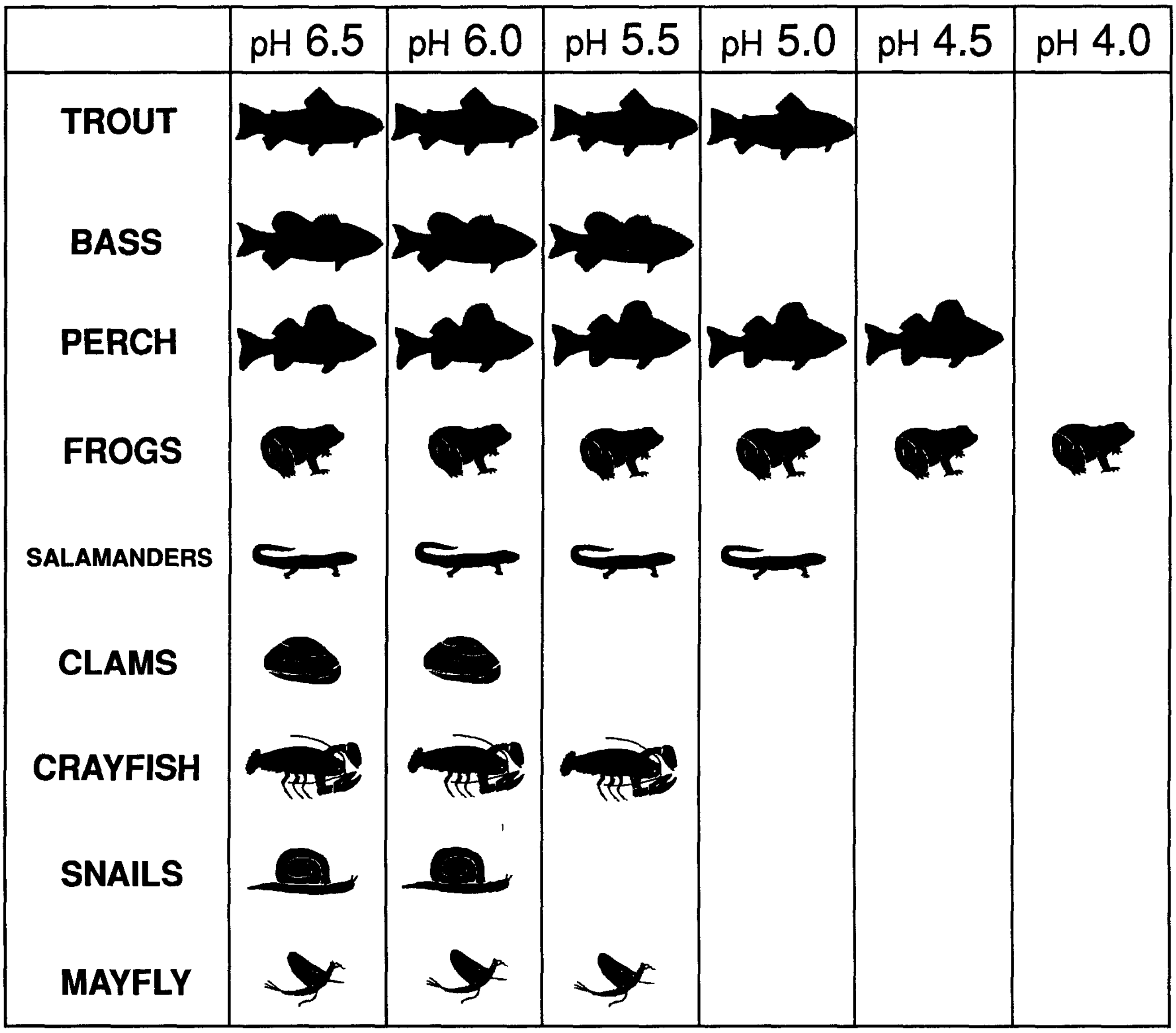
than rainfall. When leaves are frequently bathed in this acid fog, their protective waxy coating can wear away. The loss of the coating damages the leaves and creates brown spots. Leaves turn the energy in sunlight into food for growth. This process is called **PHOTOSYNTHESIS**. When leaves are damaged, they cannot produce enough food energy for the tree to remain healthy.

Once trees are weak, they can be more easily attacked by diseases or insects that ultimately kill them. Weakened trees may also become injured more easily by cold weather.

Acid rain can harm other plants in the same way it harms trees. Food crops are usually not seriously affected, however, because farmers frequently add fertilizers to the soil to replace nutrients washed away. They may also add crushed limestone to the soil. Limestone is a basic material and increases the ability of the soil to act as a buffer against acidity.

EFFECTS OF ACID RAIN ON WATER

The effects of acid rain are most clearly seen in the **AQUATIC**, or water, environments, such as streams, lakes, and marshes. Acid rain flows to streams, lakes, and marshes after falling on forests, fields, buildings, and roads. Acid rain also falls directly on aquatic **HABITATS**.



This chart shows that not all fish, shellfish, or their food insects can tolerate the same amount of acid. Fish like trout, bass, and perch are affected at different pH levels. Which type of fish are the most sensitive to acid? Generally, the young of most species are more sensitive than adults. Frogs may tolerate relatively high levels of acidity, but if they eat insects like *the mayfly, they may be affected because part* of their food supply may disappear.

Most lakes and streams have a pH between 6 and 8. However, some lakes are naturally acidic even without the effects of acid rain. Lakes and streams become acidic (pH value goes down) when the water itself and its surrounding soil cannot buffer the acid rain enough to neutralize it. In areas like the northeastern United States where soil buffering is poor, some lakes now have a pH value of less than 5. One of the most acidic lakes reported is Little Echo Pond in Franklin, New York. Little Echo Pond has a pH of 4.2. Lakes and streams in the western United States are usually not acidic. Because of differences in emissions and wind patterns, levels of acid deposition are generally lower in the western United States than in the eastern United States.

As lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease. Some types of plants and animals are able to tolerate acidic waters. Others, however, are acid-sensitive and will be lost as the pH declines. Some acid lakes have no fish. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Toxic substances like aluminum that wash into the water from the soil may also kill fish.

Together, biological organisms and the environment in which they live are called an **ECOSYSTEM.** The plants and animals living within an ecosystem are highly interdependent. For example, fish eat other fish and also other plants and animals that live in the lake or stream. If acid rain causes the loss of acid-sensitive plants and animals, then fish that rely on these organisms for food may also be affected.

EFFECTS OF ACID RAIN ON HUMAN-MADE MATERIALS

Acid rain eats away at stone, metal, paint—almost any material exposed to the weather for a long period of time. Human-made materials gradually deteriorate even when exposed to unpolluted rain, but acid rain accelerates the process. Acid rain can cause marble statues carved long ago to lose their features. Acid rain has the same effect on buildings and monuments. Repairing acid rain damage to houses, buildings, and monuments can cost billions of dollars. Ancient monuments and buildings, such as the Parthenon in Greece, can never be replaced.

Example of acid deposition effects on a monument (photo courtesy of the National Park Service).

Acid Rain, Effects on Marble (Chalk)

Calcium carbonate is a compound occurring in rocks, such as marble and limestone, and in animal bones, shells, and teeth. Marble and limestone are building materials commonly used in monuments, ancient buildings, and in many modern structures. Chalk is also calcium carbonate. Place a piece of chalk in a bowl with white vinegar. Place another piece in a bowl of tap water. Leave the dishes overnight. The next day, see if you can tell which piece of chalk is more worn away.

Experiment on Acid Effects on Metal

This experiment demonstrates the effects of acid rain on metals. Complete instructions for this and other experiments can be found in the **EXPERIMENTS** section beginning on page 25. Get two pennies that were minted before 1983. Place one penny in a cup of plain water. Place the other penny in a cup of vinegar or lemon juice. After 5 days, observe the effects of the different liquids on each penny. Observe again in two weeks.

EFFECTS OF ACID RAIN ON PEOPLE

Acid rain looks, feels, and tastes just like clean rain. The harm to people from acid rain is not direct. Walking in acid rain, or even swimming in an acid lake, is no more dangerous than walking or swimming in clean water. The air pollution that causes acid rain is more damaging to human health. Sulfur dioxide and nitrogen oxides, the major sources of acid rain, can irritate or even damage our lungs.

The pollutants that cause acid rain can also reduce visibility—limiting how far into the distance we can see.

The primary pollutants associated with acid rain and poor visibility are human-made sulfur dioxide emissions. These emissions form small sulfate particles, or aerosols, in the atmosphere. These aerosols reduce visibility by scattering light. Sulfate aerosols are the main cause of poor visibility in the eastern United States.

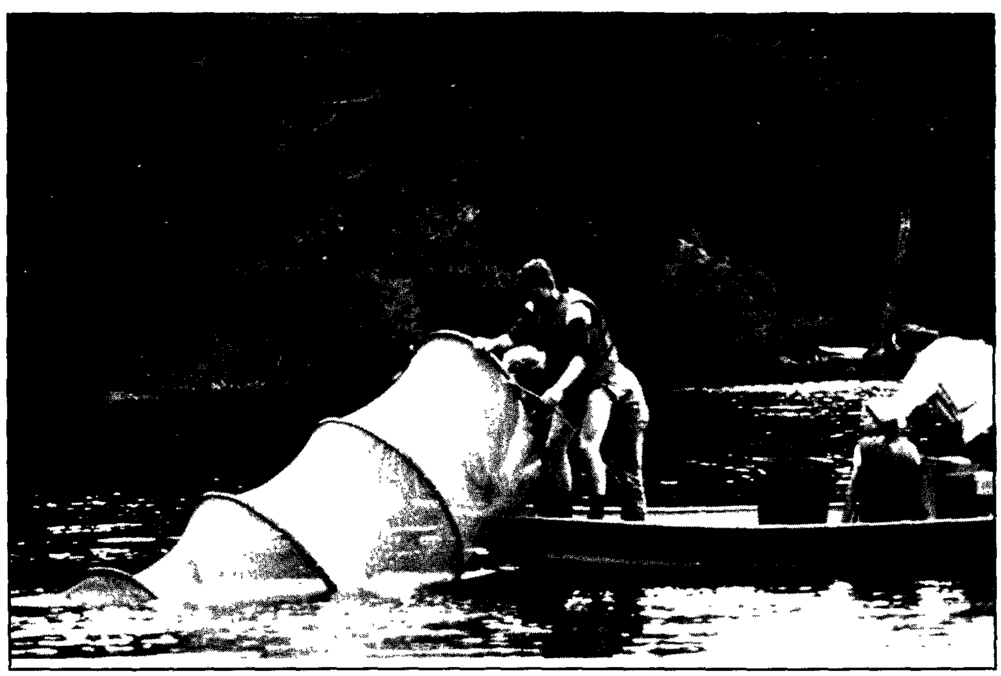
Nitrogen oxide emissions are also associated with the acid rain problem. They, too, can form aerosols in the atmosphere that significantly reduce visibility. Nitrate aerosols are often the main cause for poor visibility in the western United States where sulfur dioxide emissions and humidity are lower than in the east.

WHAT CAN BE DONE

To solve the acid rain problem, people need to understand how acid rain causes damage to the environment and what can be done to help stop acid rain. More information on the problem will help leaders make better decisions about how to control air pollution—the cause of acid rain.

Scientific Research

Experts from the United States Environmental Protection Agency (EPA) have taken samples of pollution and acidity from thousands of streams and lakes in the United States. From these samples, they determine the number of streams and lakes which are now acidic and



Scientists are collecting samples of plants and animals (photo courtesy of the U.S. Fish and Wildlife Service).

which are in danger of becoming acidic. EPA and other scientists are also studying the effects of acid rain on fish, plants, humans, and materials such as marble, brick, cement, and metal.

Until we reduce air pollution, acid rain will continue to be a problem. Activities to resolve this problem include cleaning up the smokestacks and exhaust pipes that pour pollutants into the air, finding alternative sources of energy, repairing the damage already done by acid rain, and conserving our resources.

Cleaning up Smokestacks and Exhaust Pipes

Right now, burning **FOSSIL FUELS** is one of the most inexpensive ways to produce electricity for the daily activities of modern life and to power cars, buses, and airplanes. In the United States, sulfur in coal makes up the greatest part of the sulfur dioxide that becomes acid rain. When coal is burned to make electricity or heat, the sulfur goes up the smokestacks and into the atmosphere to become air pollution.

There are several ways to reduce the amount of sulfur entering the air. One way is to wash the sulfur out of the coal before it is burned. Another is to wash the sulfur out of the smoke before it goes up the smokestacks. **SCRUBBERS** remove sulfur from the smoke by spraying a mixture of water and powdered limestone into the smokestack. This mixture traps the sulfur before it can escape into the air above.

Scientists and engineers are also discovering new ways to burn fossil fuels that produce much lower amounts of pollution.

Nitrogen oxides from burning coal and from vehicles also contribute to acid rain. Vehicles give off nitrogen oxides and other pollutants in their exhaust fumes. Devices such as **CATALYTIC CONVERTERS** reduce the pollution from those exhaust fumes. All new cars sold in the United States are required to have catalytic converters.

Alternative Ways of Producing Energy

There are other sources of energy besides fossil fuels. These include **HYDROELECTRIC POWER** and **NUCLEAR POWER**. Dams use the power of water to turn **TURBINES** and make electricity. People have been using this form of energy for most of this century. Nuclear power plants make electricity from the energy released by splitting atoms. A small amount of nuclear fuel can make a very large amount of electricity.

There are problems with using hydroelectric and nuclear power. Hydroelectric plants require a constant source of water. Because rainfall is not always predictable, hydroelectric plants are not as reliable as those using coal or oil. Hydroelectric plants can also harm the environment. Thousands of acres of land often have to be flooded to create a **RESERVOIR**, a holding place for the great amounts of water needed to power these plants. Sometimes the land that would be flooded is home to rare types of plants or animals. Nuclear power plants produce electricity cheaply. But the nuclear waste they leave remains dangerous for thousands of years.

Scientists are looking at other energy sources, such as windmills and **SOLAR ENERGY**, using the power of the sun itself. In several states, there are modern windmills like airplane propellers that make electricity from the wind. In other places, wind power pumps water from the ground. In Arizona and New Mexico, solar energy is at work making electric power. Each of these sources has drawbacks as well. Windmills and solar panels are reliable only where it is windy or sunny most of the time.

All sources of energy have benefits and limitations, including the cost of producing the energy. All of these factors must be weighed when deciding which energy source to use.

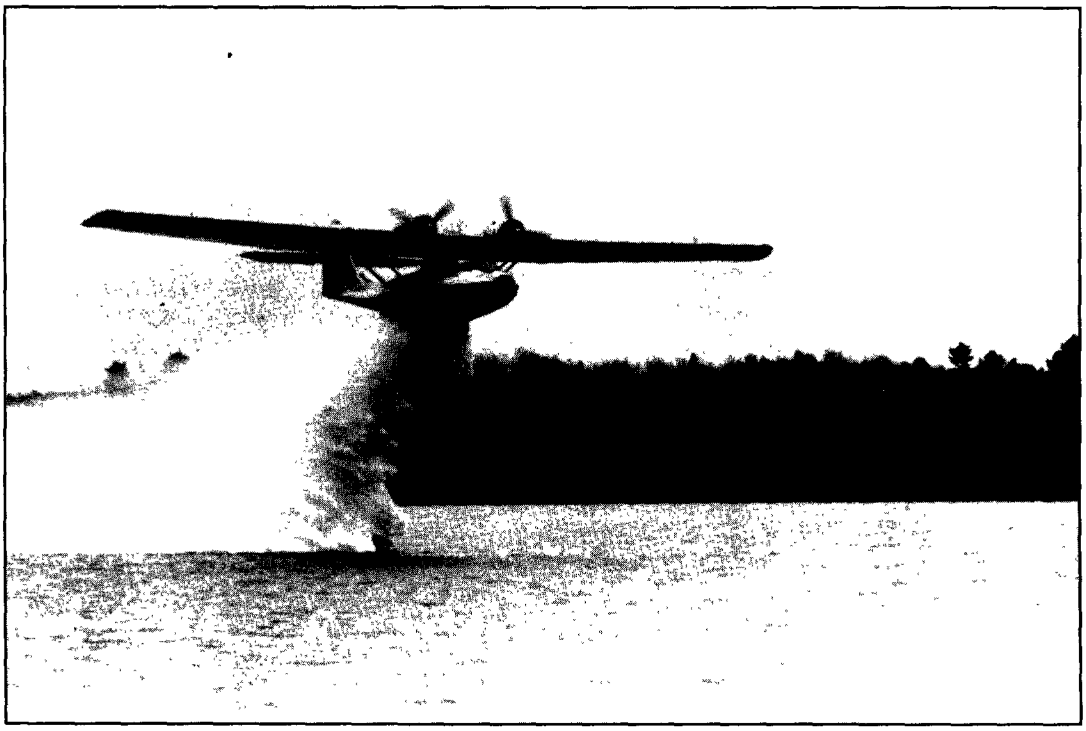
Restoring a Damaged Environment

It can take years for an acidic lake or stream to recover naturally, even if the acid rain stops. People have brought some lakes and streams back to neutral or basic conditions more quickly than nature could alone. They have added powdered limestone (a natural base) to the water in a process called **LIMING**. The people of Norway and Sweden have successfully restored hundreds of lakes and streams with liming. Few lakes and streams have been limed in the United States.

Liming is expensive and the effects are only temporary. As long as acid rain continues to fall, limestone must be reapplied or the water will become acidic again. Liming may be the only way to make sure that life in acid lakes or streams survives until the amount of acid rain falling on the surrounding land can be reduced.

Conserving Resources

It may seem like there is not much that individuals can do to stop acid rain. However, environmental problems—including acid rain—are caused by the combined actions of individual people. Individuals can take part in solving those problems as well. One of the first



Scientists are adding an alkaline material to a lake to neutralize acids in the water (photo courtesy of International Science and Technology, Inc.).

steps is to assume responsibility for the problem by finding out what can be done.

Each person who turns off lights when no one is using them and uses energy-saving appliances reduces the amount of electricity a power plant needs to produce. When less power needs to be produced, pollution from power plants decreases. Car-pooling, using public transportation, and walking reduce the pollutants that come from vehicles. The sum total of all of these individual actions can be very great indeed.

The more informed people are about acid rain and other environmental problems, the more they can do to make the earth a cleaner, healthier place. Books, pamphlets, films, and other resource materials are listed in the Bibliography of this guide, beginning on page 51.

EXPERIMENTS

For most of the following experiments, you will need a pH indicator, such as wide-range litmus or pH paper, a garden soil pH testing kit, or a pH indicator that you can make yourself (see "Making a Natural pH Indicator", Experiment #3). These pH indicators contain a chemical that changes color when it comes in contact with acids or bases. For example, litmus and pH paper turn red in strong acids and blue in strong bases. Because only a few pH indicators measure pH over a wide range of pH values, you will need to find out the pH range of the indicator you use. Typically, the color chart provided with each pH indicator kit will show the pH range of that indicator. Color pH indicators provide only an approximate measure of the pH, or the strength of the acid or base. They are not as accurate as the expensive instruments scientists use to measure pH, but they are adequate for the following experiments.

Measuring with pH Paper

When measuring pH with pH paper, dip the end of a strip of pH paper into each mixture you want to test. After about two seconds, remove the paper, and immediately compare the color at the wet end of the paper with the color chart provided with that pH indicator. Write down the pH value and color. Always use a clean, unused strip of pH paper for each mixture that you test.

Experiment Supplies

For the names of supply companies, you can consult the yellow pages of your telephone directory under a heading such as "Laboratory Equipment and Supplies." If your local directory does not have such a heading, ask your teacher for suggestions or try the yellow pages from a larger city. Telephone directories are available at many libraries.

Measuring Liquids with a Garden Soil pH Test Kit

Soil pH test kits are designed to measure the pH of soil, but they may also be used to measure the pH of liquids, such as water and water mixtures. Most of these kits contain a test solution (liquid pH indicator), color chart, and clear plastic test container, such as a test tube.

To measure pH, pour 1/4 teaspoon of the mixture you want to test into the test container, and add 1/4 teaspoon of the test solution provided in the kit. Cover the container and shake once or twice to mix, or stir if necessary. Compare with the color chart provided with the kit and write down the result.

Tips

- Except for wide-range pH test paper, all the materials called for in these experiments, including distilled water and borax, can be obtained at grocery stores or from local lawn and garden stores or nurseries.
- Wide-range pH test paper is inexpensive, but not easily obtained. A school science laboratory will probably have it or can order it, or you may order it through a biological supply company. Litmus pH paper is usually included in chemical sets sold at toy stores for children over 8 years old.
- Inexpensive garden soil pH testing kits are available at most lawn and garden stores or nurseries. These testing kits usually contain a pH indicator solution that covers a range of at least pH 4 to 10, which is wide enough for

most of the following experiments.

- You may substitute baking soda for household ammonia in the experiments. If you do, be sure to stir well because baking soda does not dissolve easily in water unless heated. The pH of undissolved baking soda will not be the same as dissolved baking soda.
- You may substitute fresh-squeezed lemon juice for white vinegar. Lemon juice is slightly more acidic than the vinegar sold in grocery stores. White vinegar is preferred over cider vinegar or lemon juice because it is colorless and relatively free of impurities.
- Use clean, dry containers and utensils.

Safety in the Laboratory

A science or chemistry laboratory can and should be a safe place to perform experiments. Accidents can be prevented if you think about what you are doing at all times, use good judgement, observe safety rules, and follow directions. Each experiment will include comments to alert you to probable hazards, including how to protect yourself and others against injury.

- Eye protection (goggles or safety glasses) must be worn when working on experiments. Make a habit of putting them on before the experiment begins and keeping them on until all clean-up is finished.
- Do not eat, drink, or smoke while in the laboratory.
- Do not taste any chemical.
- Long-sleeved shirts and leather-topped shoes must be worn at all times.
- Long hair must be tied back, so it will not fall into chemicals or flames.
- Do not work alone; work with an adult.
- Never perform any unauthorized experiment.
- All glassware must be washed and cleaned. Wipe all counter surfaces and hands with soap and water.
- All experiments that produce or use chemicals that release poisonous, harmful, or objectionable fumes or vapors must be done in a well-ventilated area.
- Never point the open end of a test tube at yourself or another person.
- If you want to smell a substance, do not hold it directly to your nose. Instead, hold the container a few

centimeters away and use your hand to fan vapors toward you.

- When diluting acids, always add the acid to the water; never water to acid. Add the acid slowly.
- Flush with large quantities of water when disposing of liquid chemicals or solutions in the sink.
- If you spill any acid or base material on you, wash the exposed area with large amounts of cold water. If skin becomes irritated, see a physician.

Recording Observations

Writing your observations on these experiments will help you to keep better track of the progress of the experiment. Written data are not forgotten. Record keeping can be very simple and still be a help. These hints can help you organize and record your thoughts.

- Use a bound notebook so that pages are not lost.
- Write complete sentences for all written entries.
- Use drawings as needed.
- Date each entry (even drawings).
- Use the title of the experiment as your first entry.
- When your observation entries have been completed, write your answers to the questions that follow each experiment.
- Write your own thoughts about the experiment as the conclusion.

Materials:

- pH paper and color chart (pH range 3 to 12) or garden soil pH testing kit
- distilled water (available at grocery stores and drug stores)
- white vinegar
- household ammonia (or baking soda)
- 3 small, clear cups or glasses
- 3 stirring spoons
- measuring cups and spoons (1/2 cup, 1/4 and 1/2 teaspoon)
- notebook and pencil

EXPERIMENT #1

Measuring pH

This experiment will illustrate how to measure the approximate pH of chemicals in water using a pH indicator. A pH indicator is a chemical that changes color when it comes in contact with acids or bases.

Instructions:

1. Rinse each cup with distilled water, shake out excess water, and label one cup vinegar, the second cup ammonia, and the third cup water.
2. Pour 1/2 cup distilled water into each of the 3 cups.
3. Add 1/2 teaspoon white vinegar to the vinegar cup and stir with a clean spoon.
4. Add 1/2 teaspoon ammonia to the ammonia cup and stir with a clean spoon.
5. Do not add anything to the water cup.
6. Dip an unused, clean strip of pH paper in the vinegar cup for about 2 seconds and immediately compare with the color chart. Write down the approximate pH value and set the cup aside. (If using a garden soil pH tester kit, pour 1/4 teaspoon of the contents of the vinegar cup into the test container, and add 1/4 teaspoon of the test solution.) Cover the test tube and shake once or twice to mix, or stir if necessary. Compare with the color chart provided in the kit, and record the result.

7. Dip an unused, clean strip of pH paper in the ammonia cup for about 2 seconds and immediately compare with the color chart. Write down the approximate pH value and set the cup aside. (If using a garden soil pH tester kit, repeat the same process in step 6 using the contents of the ammonia cup instead of the vinegar cup.)
8. Dip an unused, clean strip of pH paper into the water cup for about 2 seconds and immediately compare with the color chart. Write down the approximate pH value. (If using a garden soil pH tester kit, repeat the same process above using the contents of the water cup instead of the ammonia cup.)

Questions:

1. Is vinegar an acid or a base? (Vinegar is an acid, and in this experiment it will display a pH of about 4. Vinegar at pH 4 turns pH paper yellow and most other pH indicators red.)
2. Is ammonia an acid or a base? (Ammonia is a base and in this experiment it will display a pH of about 10. Bases turn most pH indicators blue.)
3. Were you surprised to find that the distilled water did not have a neutral pH? (Pure distilled water would have tested neutral, but pure distilled water is not easily obtained because carbon dioxide in the air around us mixes, or dissolves, in the water, making it somewhat acidic. The pH of distilled water is between 5.6 and 7. To neutralize distilled water, add about 1/8 teaspoon baking soda, or a drop of ammonia, stir well, and check the pH of the water with a pH indicator. If the water is still acidic, repeat the process until pH 7 is reached. Should you accidentally add too much baking soda or ammonia, either start over or add a drop or two of vinegar, stir, and recheck the pH.)

Materials:

- pH paper and color chart (range pH 2 to 12) or garden soil pH testing kit
- 3 fresh whole fruits (lemon, lime, orange, or melon)
- 3 beverages (cola, carbonated non-cola, milk)
- 1/8 teaspoon borax
- distilled water
- measuring spoons (1/4 and 1/8 teaspoons)
- 4 small, clear cups or glasses
- 1 clean stirring spoon
- notebook and pencil
- paring knife

EXPERIMENT #2

Determining pH of Common Substances

In this experiment you will use a pH indicator to measure the pH of some fruits, common beverages, and borax. Borax is a cleaning agent that some people add to their laundry detergent. It is available at grocery stores. Many foods and household cleaners are either acids or bases. Acids usually taste sour, and bases bitter. Household cleaners are poisons so you should never taste them.

Instructions:

1. Cut each fruit in half, drying off the knife after each cut.
2. Place an unused strip of pH paper half-on and half-off the inside of the cut fruit. Leave until wet (about 2 seconds). Immediately compare with the color chart. Write down the approximate pH value of the fruit. (If using a garden soil pH tester kit, squeeze 1/4 teaspoon of juice from the cut fruit into the test container, and add 1/4 teaspoon of the test solution. Cover the test container and shake once or twice to mix, or stir if necessary. Compare with the color chart provided in the kit, and record the result.)
3. Repeat the same process for the other 2 fruits.
4. Label the 3 cups: one cola, another non-cola, and the third milk.

5. Pour each liquid into an appropriately labeled cup.
6. Dip an unused strip of pH paper into the cola, compare with the color chart, and record the result. Repeat the same process for the remaining beverages. Be sure to use a clean, unused strip of pH paper for each one. (If using a garden soil pH tester kit, pour 1/4 teaspoon of cola into the test container, and add 1/4 teaspoon of the test solution. Tightly press your finger over the top of the test container and shake once or twice to mix, or stir if necessary. Compare with the color chart provided in the kit, and record the result.)
7. Add 1/8 teaspoon borax to 1/4 cup distilled water and stir for about 2 minutes. Dip an unused strip of pH paper in the borax mixture, compare with the color chart, and record the result. (If using a garden soil pH tester kit, pour 1/4 teaspoon of the borax/water mixture into the test container, and add 1/4 teaspoon of the test solution. Tightly press your finger over the top of the test container and gently shake, or stir if necessary. Compare with the color chart provided in the kit, and record the result.)

Questions:

1. Are lemons, limes, and oranges acids or bases?
(These fruits all contain acids and taste sour. Lemons and limes have pH values near 2. Oranges may be slightly less acidic than lemons and limes, but your pH indicator may not be accurate enough to show the difference.)
2. Are colas and non-colas acids or bases?
(They are both acidic, primarily because they contain carbon dioxide to make them fizz, and carbon dioxide and water produce carbonic acid. The pH of these beverages varies with the amount of carbon dioxide and other ingredients in them but is usually below 4.)
3. Was the milk acidic or basic?
Milk can be slightly basic or slightly acidic, depending on its age and how it was processed at the dairy.
4. Was the borax/water mixture acidic or basic?
(Borax contains a strong base and will turn most pH indicators blue. The approximate pH of the borax/water mixture is 11. Its alkaline properties make it an excellent cleaning agent, which is why some people use it to wash clothes.)

EXPERIMENT #3

Making a Natural pH Indicator

Materials:

- sliced red cabbage
- stainless steel or enamel pan or microwave casserole dish
- 1 quart water
- stove, microwave, or hotplate
- white vinegar
- ammonia or baking soda
- clear, non-cola beverage
- 3 glass cups (preferably clear)
- measuring spoons
- 3 clean teaspoons for stirring
- measuring cup (1/4 cup)
- notebook and pencil

In this experiment you will make your own pH indicator from red cabbage. Red cabbage contains a chemical that turns from its natural deep purple color to red in acids and blue in bases. Litmus paper, another natural pH indicator, also turns red in acids and blue in bases. The red cabbage pH indicator can be obtained by boiling the cabbage.

Instructions:

1. Boil cabbage in a covered pan for 30 minutes or microwave for 10 minutes. (Don't let water boil away.)
2. Let cool before removing the cabbage.
3. Pour about 1/4 cup of cabbage juice into each cup.
4. Add 1/2 teaspoon ammonia or baking soda to one cup and stir with a clean spoon.
5. Add 1/2 teaspoon vinegar to second cup, stir with a clean spoon.
6. Add about 1 teaspoon clear non-cola to the last cup and stir with a clean spoon.
7. After answering the first two questions on the next page, pour the contents of the vinegar cup into the ammonia cup.

Related Experiment: Neutralizing Acids or Bases Using a Garden Soil pH Tester Kit

Pour 1/4 teaspoon of the contents of the vinegar cup into the test container, and add 1/4 teaspoon of the test solution. Seal the top of the test container with your finger, shake once or twice, or stir if necessary, and compare with the color chart. Then pour about 1/4 teaspoon of the contents of the ammonia cup into the test container. Mix it and compare with the color chart. What happens to the pH? What would happen if you added more of the ammonia mixture? (For answers: see questions 3 and 4.)

Questions:

1. What color change took place when you added vinegar to the cabbage juice? Why?
   (The vinegar and cabbage juice mixture should change from deep purple to red, indicating that vinegar is an acid.)
2. Did the ammonia turn the cabbage juice pH indicator red or blue? Why?
   (The ammonia and cabbage juice mixture should change from deep purple to blue, because ammonia, like baking soda, is a base, which reacts chemically with the pH indicator, turning it blue.)
3. What happens to the color if you pour the contents of the vinegar cup into the ammonia cup?
   (You should find that the acid and base are neutralized, changing the color from blue or red to purple, which is the original, neutral color of the cabbage juice.)
4. If you were to gradually add vinegar to the cup containing the baking soda (or ammonia) and cabbage juice, what do you think would happen to the color of the indicator? Try it, stirring constantly.
   (As you add more vinegar, the acid level increases and the color becomes red.)
5. Is the non-cola soft drink acidic or basic?
   (It is acidic and turns the cabbage juice pH indicator red.)

EXPERIMENT #4

Measuring the pH of Natural Water

Materials:

- pH paper and color chart (range pH 2 to 7) or garden soil pH testing kit
- clean paper cups
- notebook and pencil

Questions:

1. How acidic is the water? (Based on where you live and what you have learned about acid rain, are you surprised by the result? Discuss the findings with your parents or teacher.)
2. How does the measured pH compare to the pH levels that affect plants and animals in aquatic habitats? (Refer to the chart on page 15.)

In this experiment you will measure the pH of natural water located near your home or school.

Instructions:

1. Locate a stream, river, lake, or pond. Go with an adult.
2. Scoop some of the surface water into a cup.
3. Measure the pH of the water using either pH paper or a garden soil pH testing kit (procedures described in the introduction to the experiments section) and record the result.

EXPERIMENT #5

Measuring Soil pH

Materials:

- garden soil pH test kit
- distilled water
- 2 cups soil from each of 2 or 3 different locations (some of the soil will be needed for the "Soil Buffering" experiment)
- measuring spoons
- digging tool
- self-sealing plastic bags
- notebook and pencil

In this experiment you will collect soil and measure its pH. Soil pH is one of several important conditions that affect the health of plants and animals. In addition, you will also be asked to survey the plants and animals that live in the area where you collected the soil. Area surveys provide information about how well plants and animals can live under different conditions.

For this experiment, you will need an inexpensive garden soil pH test kit, which may be obtained from lawn and garden stores or nurseries.

Instructions:

1. Pick two or three different soil locations, such as a garden, wooded area, city park, or meadow. Ask an adult to go with you.
2. At each location, observe the plants and animals living in or rooted on these soils, especially those that are in greatest numbers. Write down as much as you can about what you find. Dig down about 2 inches, scoop out 2 cups of soil, and seal it in a plastic bag for later use. Label each plastic bag. Be sure to clean your digging tool after collecting soil samples at each location.
3. Measure the pH of each soil sample following the direc-

tions provided in the garden soil pH test kit, and record the approximate pH of each soil sample. Save the excess soil from each site for use in the "Soil Buffering" experiment.

Questions:

1. Were there any big differences between the plant and animal life at each location? (Some types of plants and animals are able to live in acid soils) others are not. Be aware, however, that many factors, not just the soil acidity, determine the types of plants and animals that occur at a particular site.)

2. Were any of your soil samples acidic? (Some plants require acid soils to grow and thrive. For example, pine trees, azaleas, rhododendrons, cranberries, blueberries, potatoes, and tomatoes prefer acid soils. However, most plants thrive only in soils of pH 6 to 7.)

3. Were any of your soil samples basic? (Some soils, such as many in the midwestern United States, contain a lot of limestone and are alkaline. In those locations, people often add sulfate, such as ammonium bisulfate to soil to make it less basic.)

EXPERIMENT #6

Soil Buffering

Materials:

- pH paper and color chart (pH range 2 to 10) or garden soil pH test kit
- about 2 cups of soil from a garden, wooded area, lawn, or school yard
- distilled water
- white vinegar
- measuring cups and spoons
- stirring spoon
- large funnel
- 3 coffee filters
- paper cup
- notebook and pencil

Soil sometimes contains substances, like limestone, that buffer acids or bases. Some salts in soil may also act as buffers. In this experiment you will find out if soil from your lawn, garden, or school can buffer acids. You will observe the pH change of an acid mixture poured over soil in a filter. If the water collected from the filter is less acidic than the original mixture, then the soil is buffering some of the acid. If it does not change, then the soil may not be capable of buffering acids. Since the buffering capability of soils differs, you may want to do this experiment with several different soil types including those collected for the "Soil pH" experiment.

Instructions:

1. Pour 1 teaspoon of vinegar into 2 cups of distilled water, stir well, and check the pH with either pH paper or a garden soil pH testing kit (procedures described in the introduction to the experiments section). The pH of the vinegar/water mixture should be about 4. If it is below that, add a sprinkle of baking soda, stir well, and re-check the pH; but if it is above pH 4, add a drop or two of vinegar and again recheck the pH.
2. Put 1 coffee filter into the funnel, and fill the filter with soil from one location. Do not pack the soil down.

Questions:

1. Did the pH of the collected water stay the same as the original mixture, increase, or decrease?
(If the pH stayed the same, the soil did not buffer the acid. Each pH value above 4 indicates that the soil buffered increasing amounts of the acid. Even soil capable of buffering acids can be overpowered if enough acid is added. As more acid is added to the soil, the buffering capability decreases, and the water from the filter becomes more acidic.)

2. What can you add to the soil to increase its buffering capability?
(Limestone can be added, but it takes weeks to months for the limestone to work into the soil.)

3. Hold the filter over a paper cup and slowly pour the vinegar/water mixture over the soil until some water collects in the paper cup (the filter may clog quickly, but you need only a small amount of water).
4. Check the pH of the collected water using either pH paper or a garden soil pH testing kit and record the results (procedures described in the introduction to the experiments section).
5. Repeat the experiment with other soil samples, using a new coffee filter for each sample.

EXPERIMENT #7

Observing Influence of Acid Rain on Plant Growth

Materials:

- 4 cups or jars
- distilled water
- white vinegar
- measuring cups
- stirring spoon
- 2 cuttings of a philodendron plant (1 leaf and small amount of stem)
- 2 cuttings of a begonia or coleus plant (1 leaf and small amount of stem)
- notebook and pencil

Acid rain most often damages plants by washing away nutrients and by poisoning the plants with toxic metals. It can, however, have direct effects on plants as well. In this experiment you will observe one of the direct effects of acid water on plant growth. The experiment will take about 2 weeks.

Instructions:

1. Pour 1 teaspoon of vinegar into 2 cups of distilled water, stir well, and check the pH with either pH paper or a garden soil pH testing kit (procedures described in the introduction to the experiments section). The pH of the vinegar/water mixture should be about 4. If it is below pH 4, add a sprinkle of baking soda, or a drop of ammonia, stir well, and recheck the pH. If it is above pH 4, add a drop or two of vinegar and again recheck the pH.
2. Measure the pH of the distilled water using either pH paper or a garden soil pH testing kit. If the pH is below 7, add about 1/8 teaspoon baking soda, or a drop of ammonia, stir well, and check the pH of the water with the pH indicator. If the water is still acidic, repeat the

Question:

1. Which plant cuttings had the fastest root growth, those in distilled water or those in acid water?
(The plants grown in distilled water should grow faster than plants grown in acid water. Acid water, like acid rain, can directly damage plants and slow or stop new growth.)

process until pH 7 is reached. Should you accidentally add too much baking soda or ammonia, either start over again or add a drop or two of vinegar, stir, and recheck the pH.

3. Put one of the following labels on each cup or jar:
   water philodendron
   acid philodendron
   water begonia (or coleus)
   acid begonia (or coleus)
4. Pour about a cup of distilled water into the water-philodendron and water-begonia cups.
5. Pour about a cup of the vinegar/water mixture into the acid-philodendron and acid-begonia cups.
6. Put one philodendron cutting into each philodendron-labeled cup, covering the stem and part of the leaf with the liquid.
7. Put one begonia cutting into each begonia-labeled cup, covering the stem and part of the leaf with the liquid.
8. Set the cups where they are not likely to be spilled and where they will receive some daylight.
9. About every 2 days, check to be sure that the plant cuttings are still in the water or vinegar/water. You may need to add more liquid if the cups become dry.
10. After 1 week, compare the new root growth of each plant in distilled water with the new root growth of its corresponding plant in acid water. Record the results.
11. After 2 weeks, again observe the plant cuttings for new root growth, and record the results.

EXPERIMENT #8

Observing Buffers in Lakes, Ponds, and Streams

Materials:

- pH paper and color chart (range pH 2 to 7) or garden soil pH testing kit
- white vinegar
- distilled water
- measuring cup and spoon
- 2 stirring spoons
- 1/2 cup crushed hydrated limestone or spray limestone
- 2 cereal bowls (about 2 cup size)
- plastic wrap
- notebook and pencil

In this experiment you will observe the effects of limestone on the acidity of water. Some areas of the nation have a lot of limestone in lake bottoms and in soil, which helps neutralize the effects of acid rain. Crushed limestone is sometimes added to lakes, ponds, and other aquatic areas to help neutralize the effects of acid rain, thus preserving important aquatic systems until the source of acid rain can be reduced. Crushed limestone is easily obtained from local lawn and garden stores or nurseries.

Instructions:

1. Label one bowl vinegar; the other one vinegar plus limestone.
2. Pour 1/4 cup crushed limestone into one bowl.
3. Pour 1 teaspoon of vinegar into 2 cups of distilled water, stir well, and check the pH with either pH paper or a garden soil pH testing kit (procedures described in the introduction to the experiments section). The pH of the vinegar/water mixture should be about 4. If it is below pH 4, add a sprinkle of baking soda, stir well, and recheck the pH; but if it is above pH 4, add a drop or two of vinegar and again recheck the pH.

Questions:

1. Did the pH of the vinegar/water mixture over the limestone become more or less acidic during the 6-day period? Why? (The water mixture should have become less acidic, changing from about pH 4 to as much as pH 6, depending on the water content of the limestone you used.)
2. Does crushed limestone buffer the acid? (Yes, by neutralizing it.)
3. Did the pH of the vinegar/water mixture in the other bowl (without limestone) change during the 6-day period? (The pH of the bowl without limestone should not have changed.)

4. Pour about 1 cup of the vinegar/water mixture over the limestone in the cereal bowl and stir with a clean, dry spoon.
5. Pour the remaining vinegar/water mixture into the other cereal bowl.
6. Check the pH of the vinegar/water mixture over the limestone and record it.
7. Cover each bowl with plastic wrap to prevent evaporation.
8. Every day for 6 days, stir the contents of each bowl with a clean, dry spoon and about 4 or more hours later (after the limestone has settled), test the pH of the water mixture in each bowl and record the result.

EXPERIMENT #9

Looking at Acid Effects on Metals

Materials:

- pH paper and color chart (pH range 2 to 7) or garden soil pH testing kit
- 2 small, clear glasses (nonmetal)
- 2 clean copper pennies (use pennies minted before 1983)
- white vinegar or fresh-squeezed lemon juice
- distilled water
- plastic wrap
- notebook and pencil

When acids and metals come in contact with each other, the metal is gradually dissolved away in a chemical reaction. In this experiment you will observe this reaction for yourself, but you will need patience. The chemical effect of acids on metals may take at least five days for the human eye to see, even though the reaction starts as soon as the acid contacts the metal.

Instructions:

1. Label one glass water and the other vinegar or lemon juice depending on which acid you use.
2. Place one penny in each glass. Be sure to use pennies minted before 1983 because pennies minted after that time have a different chemical composition.
3. Barely cover one of the pennies with either vinegar or lemon juice.
4. Dip a strip of pH paper into the vinegar, or lemon juice, for about 2 seconds, compare with the color chart, and record the result. Or use a garden soil pH test kit (procedures described in the introduction to the experiments section).
5. Add enough distilled water to the glass labeled water to barely cover the other penny.

Questions:

1. What change, if any, took place in the water glass after 5 days? (There should be no change.)
2. What change, if any, took place in the vinegar (or lemon juice) glass after 5 days? (The liquid should be bluish-green. The bluish-green substance in the vinegar, or lemon juice, comes from the copper in the penny. It is a byproduct of the chemical reaction in which the acid in the vinegar, or lemon juice, very gradually eats away the penny.)
3. When you rinsed off the pennies, where you surprised that they both looked about the same as they did at the beginning of the experiment (assuming you used clean pennies)? (The chemical reaction between the acid and the copper penny is so slow that you cannot see any difference in the shape of the metal in just 5 days, at least not with your eye alone. You may see some changes after about 2 weeks, especially at the edge of the penny.)

6. Dip a strip of pH paper into the distilled water for about 2 seconds and compare with the color chart. Or use a garden soil pH test kit (procedures described in the introduction to the experiments section). If the pH is below 6, add a tiny amount (less than 1/8 teaspoon) of baking soda, or a drop of ammonia, and recheck the pH. Repeat this process until the pH is between 6 and 7. Record the pH of the water.
7. Seal the top of each glass with plastic wrap to prevent evaporation.
8. Place in a safe, dry place for about 5 days.
9. After about 5 days, observe the changes that occurred in each glass.
10. At the end of the experiment, wash off the pennies with water, and pour the contents of the glasses down the sink (do not drink).

ACTIVITIES

• Classroom: Collect acid rain and air pollution cartoons from newspapers and magazines. Display and discuss them.

• Classroom: Imagine that you are all scientists. Think about a research project to investigate some aspect of acid rain—how it forms, the damage it does, etc. Write your ideas on the board. Discuss the questions you would ask and the steps you would take to do the research. If possible, invite a local research scientist to the classroom to review your project and comment on it.

• Small groups or individuals: Write, produce, and direct a special segment for a T.V. "weather special" on the effect of weather patterns on the travel of acid rain over large distances. Contact the weather bureau or a local television station's weather department to ask about the wind patterns in your area.

• Class Trip: Visit a nearby science center or museum of science. Request information on educational programs for acid rain. Look for exhibits that relate to the causes and effects of acid rain and how acid rain travels (weather). Note: If there is no such museum nearby, write to the nearest one and request information on educational programs or their exhibits that deal with acid rain and its effects.

• Individual students: Design a word-find puzzle using the words in the **GLOSSARY** of this guide.

• Individuals: Contact a local **NATURAL RESOURCE SPECIALIST** from your local zoo or park and ask that person to tell you about the impact, if any, of both acid rain and dry deposition in the lakes, forests, or other natural resources in your area. (An alternative to this would be for the class to invite a specialist to come and speak on this topic.) Write down what you have learned in a report to be given to the teacher or read to the class.

• Classroom: Role playing. Each of you takes the role of an "interested party" (for example, a fish, bird, coal miner, factory owner, smokestack, fisherman, farmer, stream, lake, tree, or forester) in a group discussion on acid rain. Talk about the effects acid rain has on your character and then present arguments for or against laws to control acid rain.

• Field Trip: Visit a local cemetery and observe the wearing away of the headstones or other grave markers over time. Military cemeteries use limestone markers which are more easily affected by acid rain than the granite markers in some private cemeteries. Can you tell by the dates on the marker stones and the condition of the stones which ones acid rain may have damaged? Remember that these materials would naturally deteriorate when exposed to the weather and rain (even clean rain). Acid rain would accelerate this damage.

• Individual research: Contact your local power company. Many power companies use more than one source of power to make enough electricity for the community. Some also buy electricity from other power companies. Ask the power company which is its primary source (hydroelectric, nuclear, gas, oil, coal, other) and what other sources it uses. If they can tell you, find out what percent of their output is generated by each source. If your company buys from other companies ask if they know what source generates that company's electricity. Write down your results in a report to be read to the class.

• Class or individual: Locate or list energy efficient buildings in your community. Contact a local architect or an architecture department in a local college or university and invite an architect to visit your classroom to describe how homes, schools, and office buildings can use energy more efficiently.

• Individual: Find out if your drinking water is being treated for acidity. Call or visit the water company. First determine the source of your water—well, lake, or river. If you have a private source of water such as your own well, ask your parents if the water is treated, and if so, how it is treated. When talking to a water company, usually a city or county water authority, ask if and how they treat the water for acidity. Ask them to tell you the pH of the water before it is treated and the pH after it is treated. Is it completely neutralized? Write down their answers in a report to give to the teacher or read to the class.

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Earth Metabolic Design
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"For the Long Run" (video, 20 minutes)
National Park Service
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GLOSSARY

Acid Any of a large group of chemicals with a pH less than 7. Examples are battery acid, lemon juice, and vinegar.

Acidic Describes an acid. For example, lemon juice is acidic.

Acid Rain Wet precipitation that has become acidic by contact with air pollution. Other forms of precipitation, such as snow and fog, are also often included in the term acid rain or acid deposition.

Alkaline Describes a substance such as baking soda, milk of magnesia, or ammonia, that can dissolve in water and neutralize acids.

Aquatic Growing or living in water.

Atmosphere The air or gases that surround a planetary body such as the earth.

Base Any of a large group of chemicals with a pH greater than 7. Examples are ammonia and baking soda dissolved in water.

Basic Describes a base. For example, alkaline materials are basic.

Buffer A substance, such as soil, bedrock, or water, capable of neutralizing either acids or bases.

Buffering Capacity The ability of a substance to resist changes in pH when acids or bases are added.

Carbon Dioxide A colorless, odorless gas made of the elements carbon and oxygen. Animals exhale carbon dioxide and automobile exhaust contains carbon dioxide.

Catalytic Converter A device that burns off pollution from exhaust gases. Commonly used in automobiles and required on all cars sold in the United States since 1973.

Chemical A substance made up of elements combined together.

Condense To change from gas or vapor to liquid form.

Dry Deposition The falling of small particles and gases to the earth without rain or snow.

Ecosystem The relationships among animals and plants and their environment in a particular area.

Energy The power to do physical work. Electricity and heat are energy sources.

Environment The combination of all conditions surrounding living things.

Fossil Fuels Oil, natural gas, coal, and similar products that are taken from the earth and used for energy. Fossil fuels were made in nature from ancient plants and animals.

Habitat The place where a plant or animal lives and grows, such as a forest, lake, or stream.

Hydroelectric Power The production of electrical energy using water power.

Hydrologic Cycle The movement of water from the atmosphere to the surface of the land, soil, and plants and back again to the atmosphere.

Limestone A rock that is made from ancient shells and coral. Limestone contains calcium carbonate and is a base.

Liming Adding crushed limestone to lakes, streams, or other bodies of water is called liming and it raises the pH of the water.

Litmus Paper Paper coated with a chemical coloring obtained from lichens that turns red in acidic water and blue in basic water. It is used as an acid-base indicator.

Natural Resources All the parts of the earth that are not human-made and that people use, like fish, trees, minerals, lakes, or rivers.

Natural Resources Specialist A person who knows a great deal about animals and plants and where they live—for example, naturalist, forester, forest ranger, etc.

Neutral A substance that is neither an acid nor a base and has a pH of 7. Neutral substances can be created by combining acids and bases.

Neutralize To combine acids and bases to make a neutral substance or solution. For example, acidic water can be neutralized by adding a base, such as limestone.

Nitric Acid An acid that can be produced in the atmosphere from nitrogen oxide.

Nitrogen Oxides A family of gases made up of the elements nitrogen and oxygen commonly made by burning fossil fuels.

Nuclear Power Energy that comes from the center (nucleus) of an atom.

Oxidants Chemicals that supply oxygen to other chemicals when they are combined in a chemical reaction.

Particles Tiny solid fragments that float in the air, such as dust.

pH Scale The range of units that indicate whether a substance is acidic, basic, or neutral. The pH scale ranges from 0 to 14; a pH of

7 is neutral, lower than 7 is acidic, and greater than 7 is basic.

pH Paper Paper that changes color to show the pH of a substance.

Photosynthesis The process that plants use to convert sunlight to energy to live and grow.

Plankton Tiny organisms that float or drift in water and serve as a food source for larger animals such as fish.

Precipitation Mist, sleet, rain, hail, or snow falling to the earth.

Pollutant A harmful chemical or other unwanted substance released into the environment by human activity.

Pollution Chemicals or other substances that are harmful to or unwanted in the environment.

Reactive Having the tendency to chemically combine with something else and change its form. For example a strong acid is highly reactive with a strong base.

Reservoir A place where water is collected and stored for use, usually in an artificial basin created by damming a river.

Runoff Water that flows off land into lakes and streams.

Scrubber A device that removes air pollution, mainly sulfur dioxide, from smokestacks.

Solar Energy Energy that comes from the sun.

Solution A uniform mixture formed by dissolving a substance in liquid.

Sulfur Dioxide A gas made of sulfur and oxygen that is released when coal is burned.

Sulfuric Acid An acid that can be produced in the atmosphere from sulfur dioxide. Sulfuric acid is used in automobile batteries.

Toxic Poisonous to some living thing.

Turbine A motor activated by water, steam, or air to produce energy.

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