

Acid Rain Study Guide

ACID RAIN STUDY OUTFIT

CODE 3604-01

| QUANTITY | CONTENTS | CODE |
|----------|--|---------|
| 2x 30 mL | *Wide Range pH Indicator | *2218-G |
| 2 | Test Tubes, 2.5-5-10 mL, plastic, w/caps | 0106 |
| 1 | Wide Range pH Octa-Slide 2 Bar, 3.0-6.5 | 2193-01 |
| 1 | Wide Range pH Octa-Slide 2 Bar, 7.0-10.5 | 2196-01 |
| 1 | Octa-Slide 2 Viewer | 1101 |

*WARNING: Reagents marked with an * are considered to be potential health hazards. To view or print a Safety Data Sheet (SDS) for these reagents go to www.lamotte.com. Search for the four digit reagent code number listed on the reagent label, in the contents list or in the test procedures. Omit any letter that follows or precedes the four digit code number. For example, if the code is 4450WT-H, search 4450. To obtain a printed copy, contact LaMotte by email, phone or fax.

Emergency information for all LaMotte reagents is available from Chem-Tel (US, 1-800-255-3924) (International, call collect, 813-248-0585).

CONTENTS

| | |
|---|----|
| pH | 3 |
| Rain | 4 |
| Effects of Acid Rain | 6 |
| Measuring Rainfall - the Rain Gauge | 8 |
| Use of the Octa-Slide 2 Viewer | 9 |
| Measuring pH | 10 |
| Testing pH of Other Solutions | 11 |
| Suggestions for the Use of the Chemical Testing Equipment | 12 |
| Notes to the Teacher | 12 |
| Glossary of Terms | 13 |

WARNING! This set contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision

The pH of a liquid, soil or other substance indicates whether a substance is acidic, neutral, or basic. The pH measurement is based on the number of hydrogen ions (H^+) or hydroxyl ions (OH^-) there are in a solution of the substance. If the solution has more hydrogen ions than hydroxyl ions, the solution is acidic. On the other hand, if the hydroxyl ions outnumber the hydrogen ions, the solution is basic. When both the hydrogen ions and hydroxyl ions are present in equal numbers, the solution is neutral.

THE pH SCALE

The pH scale ranges from 0 (very acid) to 14 (very alkaline or basic). On this scale a neutral substance is 7 (the mid-point of the scale), an acid substance is lower than 7 on the scale, and a basic or alkaline substance is higher than 7 on the scale. (Fig. 1) When an acid and a base react, neutralization occurs. The result is a solution that is not as acidic or as basic as the original substances. It is important to know that the pH scale is logarithmic. Every one-unit change in pH represents a ten-fold change in acidity or alkalinity. In other words, pH 6 is ten times more acidic than pH 7; pH 5 is one hundred times more acidic than pH 7. Pure distilled water has a pH of 7 but quickly becomes slightly acidic when exposed to air. This is also the case with rain water in the atmosphere.

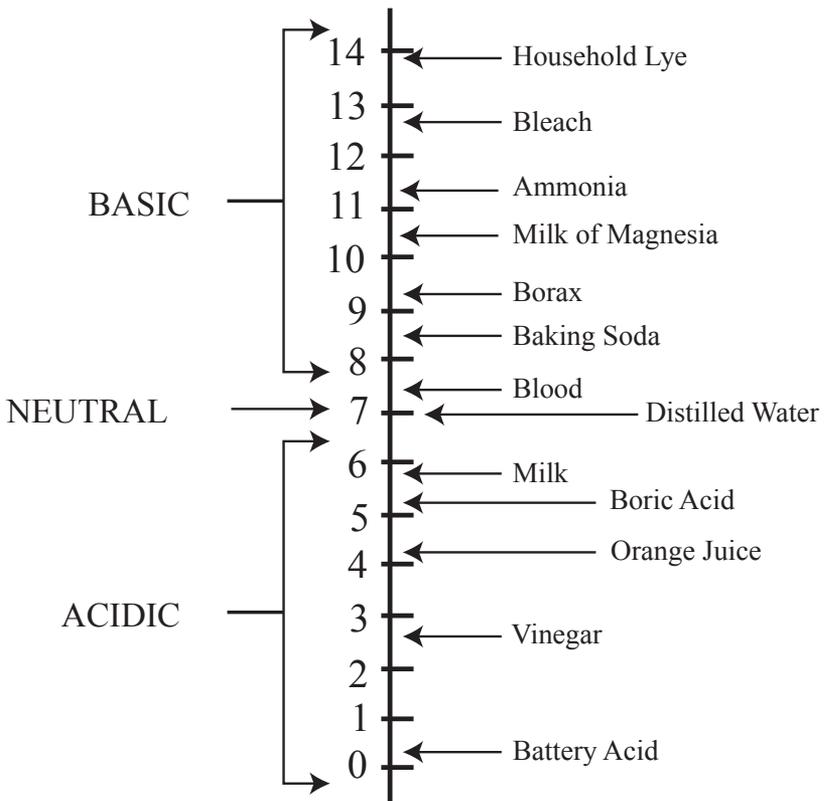
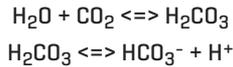


Fig. 1 The approximate pH values of some common substances.

RAIN

Normal rain may have a pH as low as 5.6 due to the absorption of small amounts of carbon dioxide (CO_2) in the atmosphere. The carbon dioxide reacts with rainwater to form carbonic acid (H_2CO_3). The pH of the rain is lowered because a small portion (about 10% or less) of the carbonic acid dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+):



Carbonic acid is a weak acid which can be easily neutralized by the buffering substances found in streams, lakes, and soil.

ACID RAIN

Precipitation having a pH less than 5.6 is considered to be abnormally acidic. A pH of less than 5 indicates the presence of strong acids in addition to carbonic acid.

CAUSES OF ACID RAIN

Acid rain is formed from air pollutants, sulfur dioxide and nitrogen oxides, which are released as gases into the atmosphere during the refining of metal ores and the burning of fossil fuels such as coal, heating oil and gasoline. Power plants, smelters, automobiles, and even volcanic activity can contribute to this problem. These gases may travel miles from their sources. Eventually, they combine with moisture in the atmosphere to form sulfuric acid and nitric acid solutions which fall to earth in rain, snow, dew, fog, frost, and mist.

SULFUR DIOXIDE (SO_2)

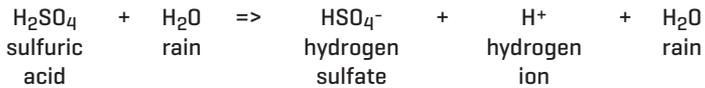
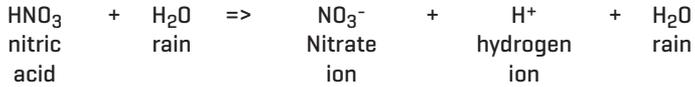
When fuel or coal that contains sulfur is burned, the sulfur compounds react with oxygen during combustion to form sulfur dioxide. Sulfur dioxide is also produced when sulfite ores such as sphalerite ($(\text{Zn,Fe})\text{S}$), pyrite (FeS_2), and chalcocite (Cu_2S) are roasted or heated in air during the production of the metals zinc, iron, and copper. Sulfur dioxide also occurs in volcanic gases. The “rotten egg” odor of burning sulfur is due to sulfur dioxide.



NITROGEN OXIDES (NO_x)

Internal combustion engines in automobiles, trucks, and other vehicles produce gaseous nitrogen oxides (NO_x) because nitrogen and oxygen from the air combine during combustion. Lightning during thunderstorms also forms nitric oxides by the direct union of nitrogen and oxygen in the air.

Sulfur dioxide and nitrogen oxides dissolve in atmospheric moisture to form nitric acid and sulfuric acid. Nitric acid and sulfuric acid are strong acids. They dissociate completely as carbonic acid in rain water to form hydrogen ions, making the pH of rain water more acidic.



EFFECTS OF ACID RAIN

EFFECTS ON MATERIALS

Acid precipitation can affect many of the materials we depend on every day. The rusting of metals is an oxidation reaction that is accelerated by the presence of acidic rain, fog and dew. Corrosion of steel, bronze and copper is increased, affecting the condition and maintenance costs of buildings, bridges, and vehicles. Acid rain hastens the natural weathering of marble, limestone and mortar. These substances are composed of calcium carbonate (CaCO_3) which reacts with sulfuric acid in acid rain to become water, carbon dioxide, and powdery gypsum. The durability of paints and textiles are also affected. In many areas, rain water is used for drinking purposes. The pH of water must be carefully adjusted to make it non-corrosive before it is circulated in plumbing systems that contain metal components so that metals will not enter drinking water.

EFFECTS ON STREAMS, PONDS AND LAKES

A healthy, productive freshwater lake has a pH of about 8, slightly basic. The pH level is maintained at a steady level by the presence of “buffering” chemicals in the water, primarily carbonate and bicarbonate ions. The buffering chemicals in a stream, pond or lake are an indication of the types of soils, minerals and rocks in the area. In some areas, borate (BO_3^{-3}), phosphates (PO_4^- , HPO_4^- , and H_2PO_4^-), and silicates contribute to the buffer system. The amount of basic buffering materials in the water is termed the “alkalinity” of the water. The “alkalinity” of water does not refer to pH but rather the ability to resist pH changes (buffering capacity).

The presence of these buffering materials helps to neutralize acids as they are added to or created in the water ecosystem. If a body of water has an abundance of these buffering materials (high alkalinity), it is more resistant to changes in pH. If a body of water has very little buffering material (low alkalinity), it is very susceptible to changes in pH.

As increasing amounts of acids are added to ponds and lakes, their buffering capacity is consumed. If additional buffering material can be obtained from surrounding soils and rocks, the alkalinity level may eventually be restored. However, a temporary loss of buffering capacity can permit pH levels to drop to levels harmful to life in the water.

An entire season of acid precipitation can be stored up in the form of snow and ice. Areas which receive a lot of snowmelt each spring are especially susceptible to the seasonal loss of buffering capacity.



EFFECTS ON AQUATIC LIFE

The pH of natural waters does not fall evenly as acid contamination proceeds. The natural buffering materials in water slow the decline of pH to around 6.0. This gradual decline is followed by a rapid pH drop as the bicarbonate buffering capacity is used up. At pH 5.5, the buffering capacity is very low and pH drops further with additional acid. Sensitive species and immature animals are affected first. As food species disappear, even larger, resistant animals are affected.

pH EFFECT ON AQUATIC LIFE

| | |
|------------|---|
| 6.0 | Freshwater shrimp absent |
| 5.5 | Bottom-dwelling bacteria (decomposers) begin to die Leaf litter and detritus begin to accumulate, locking up essential nutrients and interrupting chemical cycling Plankton begin to disappear Snails and clams absent Mats of fungi begin to replace bacteria in the substrate Metals (aluminum, lead) normally trapped in sediments are released into the acidified water in forms toxic to aquatic life |
| 5.0 | Mayfly and many other insect eggs will not hatch Most fish will not hatch |
| 4.5 | All fish, most frogs, insects absent Sphagnum moss may invade, covering the substrate and inhibiting nutrient cycling |

EFFECTS ON PLANTS AND SOILS

The leaves of living plants are covered with a protective waxy cuticle. Acid deposition (dust, rain, fog, dew) damages this coating, permitting desiccation of leaf tissues and leaching important nutrients directly from the leaves. Damaged plants become more vulnerable to drought and disease.

The pH of soil affects the availability of nutrients to plants growing in the soil. When acid precipitation infiltrates forest soils, important cations such as potassium (K^+) and calcium (Ca^{++}) may be displaced by the hydrogen ions of the acid. The cations can then be “leached” away by groundwater and surface runoff. In areas where the soil contains limestone or calcite, much of the acidity can be neutralized. However, in areas with thin soils overlying granite rocks, the runoff of acid precipitation to lakes and streams will be acidic and may contain ions leached from the soil, such as aluminum, which is toxic to fish at levels less than 1 part per million.

Soil acidification also inhibits helpful soil bacteria, limiting nitrogen fixation and nitrification in the soil and slowing the decomposition of organic matter.

MEASURING RAINFALL - THE RAIN GAUGE

Place the rain gauge in an open area far enough from buildings, trees, overhead wires and other obstructions that may cause air turbulence or contamination. Rain falling on rooftops or trees collects chemicals which will affect the pH. There should be no obstruction above a 45 degree angle from the top of the rain gauge. In other words, locate the rain gauge at least 20 feet away from a 20 foot tall obstruction (Fig. 2).

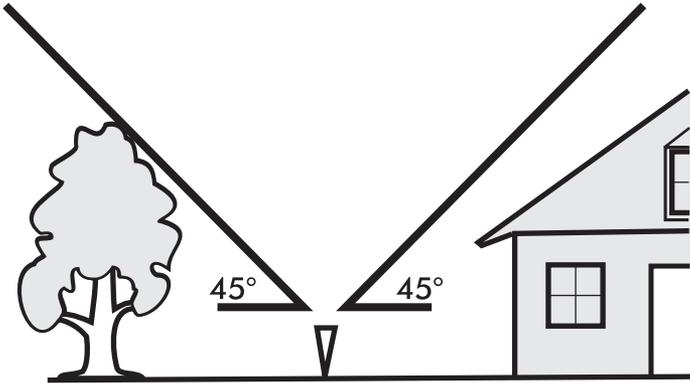


Fig. 2 Proper placement of rain gauge

A plastic spike serves as the base for the rain gauge. Select a location for the rain gauge and push the spike straight into the ground so that the top of the rain gauge is parallel to the ground. The rain gauge can also be mounted on a post by using the screws included to fasten the base unit in a vertical position. Record the amount of rainfall and empty the rain gauge after each rain event before evaporation occurs. The rain gauge can collect up to 5" of rain. During a very heavy storm, the rain gauge may be recorded, emptied, and reset. Record the partial readings and add them to figure the total rainfall for the storm event.

Do not leave the rain gauge outdoors in freezing weather.

USE of the OCTA-SLIDE 2 VIEWER

The Octa-Slide 2 Viewer should be held so non-direct light enters through the back of the Viewer. Slide the Octa-Slide 2 Bar into the Viewer. Insert the reacted sample into the top of the Viewer. Match the color of the reaction to the color standards.

PROCEDURE

1

Insert Octa-Slide 2 Bar into the Octa-Slide 2 Viewer.



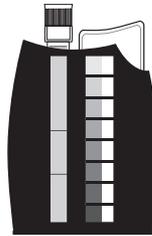
2

Insert test tube into Octa-Slide 2 Viewer.



3

The Octa-Slide 2 Viewer should be held so non-direct light enters through the back of the Viewer. Match the color of the reaction to the color standards.



MEASURING pH

A pH test indicates whether a substance is acidic, basic, or neutral. Scientists take pH measurements for water, soil, food, and many other substances. The pH of a substance can be measured by adding pH indicator solutions to the substance. The pH indicators are dyes that change color according to the pH of the solution. These colors are then compared to color standards of a known pH value.

RAIN pH TEST

When a rain storm is expected, carefully clean and thoroughly rinse the rain gauge. (Dust and other airborne residue inside the rain gauge will affect the pH of the collected rain.) Rinse the rain gauge and pH kit test tubes with distilled or deionized water and hang upside-down to dry. Place the rain gauge outdoors in its holder immediately before the rain begins. Perform the pH test as soon as possible after the rain has fallen.

| | |
|--|--|
| <p>1</p>  <p>Insert Wide Range pH Octa-Slide 2 Bar (2193-01 or 2196-01) into the Octa-Slide 2 Viewer (1101)</p> | <p>2</p>  <p>Fill a clean test tube (0106) to the 10 mL line with rain water from the rain gauge.</p> |
| <p>3</p>  <p>Add 10 drops of *Wide Range pH Indicator (2218). Cap and mix.</p> | <p>4</p>  <p>Insert test tube into Octa-Slide 2 Viewer (1101). Match sample color to a color standard. Record as pH.</p> |

NOTE: If the color observed in your sample is between two colors on the comparator, the value may be reported to the nearest 0.25 pH unit. If the color produced by your sample is not in the range of the color standards in the comparator, use the following chart to estimate the pH of the sample:

pH 7 apple-green

pH 8 green

pH 9 blue-green

pH 10 blue

pH 11 purple

TESTING pH OF OTHER SOLUTIONS

The *Wide Range Indicator (2218) included in this kit can be used to measure the pH of solutions ranging from 3.0 to 10.0 pH. Surface water, tap water, foods and household products can be tested.

TESTING THE pH OF STREAMS, LAKES, AND PONDS

1. Select a sampling location where the water sample is typical of the water source and does not represent a localized condition. For example, a water sample taken next to a discharge pipe may not contain the same types and amounts of substances that would be found in a sample collected away from the discharge pipe.
2. Record the date and time of day, weather and other observations such as water color, the presence of aquatic plants, algae, insects, or fish.
3. Keep the water sample free of foreign matter such as aquatic plants or sediment from the bottom.
4. Use a clean, plastic or glass water sample container that has a suitable cap. The container should hold enough water to conduct all of the tests.
5. Unless the sample is going to be tested immediately, the water sample container should be filled until it overflows and then capped. Avoid air bubbles in the sample that can cause chemical changes in the water. Water samples should be tested as soon as possible.

TESTING THE pH OF HOUSEHOLD PRODUCTS

Test the pH of a number of household products that are readily available from your home or school. For solutions which are not highly colored, the pH test can be made without any preparation of the sample. Substitute a sample of the colorless material for the water sample in the procedure above.

Solutions which are cloudy or colored may be filtered or diluted with distilled water before the pH test is performed. (Distilled water is unbuffered and will not significantly affect the pH of a strong sample.)

Use the chart in the preceding section to identify the pH of the solution.

NOTES TO THE TEACHER

The materials and manual in this kit are provided as the tools needed to conduct many important investigations. It is hoped the students' and teachers' interest will not be limited to the experiments or procedures as they are outlined in this manual. They provide the basic information needed to conduct many fascinating investigations and activities. A number of suggested activities are provided in the form of additional, open-ended experiments. They should spur the student's imagination to investigate other problems which are related to the subject. The inquiring student may devise other experiments using the materials provided in this unit or they may make modifications to the methods and incorporate additional materials and test kits.

SUGGESTIONS ON THE USE OF THE CHEMICAL TEST EQUIPMENT

- A. Follow all of the instructions carefully. Read to the end of each procedure before starting the actual work. Measure reagents and water samples accurately.
- B. Handle the reagents with great care. Avoid contact between the reagents and the skin and eyes. Some of the reagents are capable of causing minor skin irritations if they are not washed off immediately after contact. None of the reagents should be taken internally.
- C. Keep all reagent containers tightly capped. Replace the cap immediately after use. This prevents contamination and eliminates the possibility of loss of the reagent due to leakage or spilling. Do not interchange caps.
- D. The test tubes should be rinsed thoroughly in clean tap water and allowed to dry before putting them back into the package. No soap or detergents are required unless there are stubborn stains which will not come out in clean tap water. If soaps or detergents are used, be sure to rinse the test tubes several times before allowing them to dry.
- E. Avoid storing the equipment where it will be exposed to extreme heat or cold. Do not leave the reagents exposed to direct sunlight for a prolonged period of time. Store the equipment and reagents out of the reach of very young children.

GLOSSARY OF TERMS

Absorption - The addition of one substance through the surface of another.

Acid - A compound that donates a hydrogen ion (H^+).

Acid Deposition - The depositing of acidic material from the atmosphere as gases, particles, rain, snow, or fog.

Acidic - The degree or level of the acid content of a substance. An acidic substance is below 7.0 on the pH scale.

Algae - Simple rootless plants that grow in sunlit waters in proportion to the amounts of nutrients available. Algae have chlorophyll which is used to convert solar energy (sunlight) to chemical energy. They are food for fish and small aquatic animals.

Alkalinity - A measure of the capacity of water to neutralize acids.

Aquatic - Living or growing in a water environment.

Bacteria - Microscopic living organisms which help break down complex substances, such as dead animal and plant matter, by decay, and convert these substances to simpler forms.

Base - A compound that accepts a hydrogen ion (H^+).

Basic - A basic substance is above 7.0 on the pH scale.

Buffer - A substance that resists pH changes when small amounts of acid or base are added.

Carbon Dioxide (CO_2) - A colorless, odorless, non-poisonous gas, which is a normal part of the ambient air.

Corrosion - The deterioration of metal parts slowly eaten away by acid solutions or acid water supplies.

Detritus - Dead plant and animal material.

Fungus - A primitive group of organisms that lack chlorophyll; includes the mushrooms, molds, mildews, yeasts, rusts and smuts which live primarily on dead or living organic matter.

Groundwater - Water that has soaked into the ground; often used to supply wells.

Hydroxyl Ion (OH^-) - A negatively charged particle containing an oxygen atom and a hydrogen atom. See pH.

Hydrogen Ion (H^+) - A positively charged particle containing only a hydrogen atom. See pH.

Indicator Solution - A liquid containing a chemical compound added to a test sample to bring about a color reaction to show the presence or absence of a particular substance.

Leaching - The removal of dissolved chemical compounds by the passage of water through soil.

Leaf Margin - The border or edge on a leaf. A leaf margin may take many shapes or forms such as smooth, saw-like, or tooth-like.

Litmus Paper - Paper which is soaked in a coloring matter obtained from primitive plants called lichens. In alkaline solution litmus turns blue; in an acidic solution litmus turns red.

Mineral Deficiency Disease - A disease in plants which is caused by the lack of one or more of the important plant nutrients.

Neutral - A substance that is neither acidic nor basic but having a pH of 7.0 on the pH scale.

Nitrogen Oxides - Gaseous compounds of oxygen and nitrogen which can contribute to air pollution.

Nutrient, Plant - Any element taken in by a plant which is essential to its growth. Nutrients are used by the plant to produce food and tissue.

Organic Matter - Animal and plant materials that are decomposed through the action of micro-organisms.

Oxidation - The process by which oxygen combines with other compounds to change their chemical state.

pH - The concentration of hydrogen ions in a substance. A pH scale is used to indicate whether a substance is acidic, neutral, or basic.

Plankton - Very small plants and animals that live in water.

Pollution - The presence of matter or energy whose nature, location, or quantity produces undesired environmental effects.

Root Hairs - Very small roots of plants which take up nutrients from the soil solution.

Run-off - The portion of precipitation or snow melt that runs off the land into streams or other surface water.

Solution - One or more substances dissolved in a liquid.

Sediments - Soil, sand, and minerals that wash from the land into water and settle to the bottom of streams and lakes.

Smelter - A facility that melts or fuses ore to separate metals.

Sulfur Dioxide (SO₂) - A heavy, pungent, colorless and gaseous air pollutant.

Surface Water - All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.); also springs and wells which are directly influenced by surface water.

Weathering - The disintegrating action of the elements (wind, rain, sleet, snow, freezing, and thawing) on rocks and soils.

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