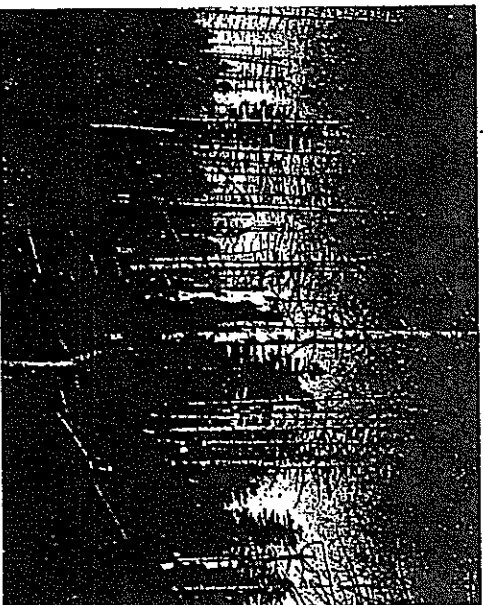


# Chemistry Serving...the Environment

## RAIN LIKE VINEGAR

In Canada and the eastern part of the United States, lakes once full of fish and frogs are now nearly lifeless. Acres and acres of pines and other forest trees are dying in the Appalachian Mountains. In Rome and Athens, ancient carved stonework has been weathered so badly that the details of the carvings have been erased. All this damage



has a single cause—acid rain.

Acid rain is rain with a pH lower than that of "normal" precipitation. Normal precipitation is itself mildly acidic, with a pH of about 5.6. This mild acidity comes from small amounts of carbon dioxide in the atmosphere that dissolve in tiny water droplets to form carbonic acid ( $\text{H}_2\text{CO}_3$ ). The acidity of normal rainfall poses no problems because it is so mild and because animals and plants have adapted to it. But when the pH of rainfall gets significantly lower than 5.6, negative effects begin to appear. The rain from a 1981 storm in Baltimore was measured at pH 2.7, about the same pH as vinegar! Where it occurs, acid rain causes enormous damage to stone structures, paint, metal, and the environment. It leaches nutrients from the soil and may even be a direct threat to human health. What causes acid rain? Acid rain results when oxides of sulfur ( $\text{SO}_2$ ) and oxides of nitrogen ( $\text{NO}_x$ ) are emitted into the atmosphere. Although there are some natural sources of these pollutants (such as volcanoes),

most of them come from human sources, such as coal- and oil-fired power plants. In the atmosphere, sulfur oxides form sulfuric acid ( $\text{H}_2\text{SO}_4$ ), and nitrogen oxides form nitric acid ( $\text{HNO}_3$ ). Eventually, these acids fall to Earth in rain-drops or snowflakes. Fortunately, acid rain can be prevented, and chemistry is playing a big part in the effort. Because power plants are one of the main sources of  $\text{SO}_x$  and  $\text{NO}_x$ , chemists have focused on developing devices called scrubbers that remove these pollutants from power plant smoke before it leaves the smokestack.

**The rain from a 1981 storm in Baltimore was measured at pH 2.7, about the same pH as vinegar!**

In one type of scrubber now in common use, the smoke passes through an aqueous suspension of lime (CaO). The lime reacts with the gaseous  $\text{SO}_2$  to make calcium sulfite ( $\text{CaSO}_3$ ), a solid that can be disposed of. To remove  $\text{NO}_x$ , a process called Selective Catalytic Reduction (SCR) is often used. In an SCR chamber, ammonia ( $\text{NH}_3$ ) is sprayed onto a surface

covered with a mixture of catalysts. As the smoke passes through the chamber, NO and  $\text{NO}_2$  in the smoke react with the ammonia and oxygen to form harmless nitrogen gas ( $\text{N}_2$ ) and water ( $\text{H}_2\text{O}$ ).

To eliminate the need for separate scrubbers for  $\text{SO}_x$  and  $\text{NO}_x$ , researchers have also developed ways of removing the two types of oxides from power plant smoke at the same time. In one technique, the smoke is passed through an alkaline suspension of yellow phosphorus. A variety of chemical reactions occur that convert almost all the  $\text{SO}_x$  and  $\text{NO}_x$  into valuable by-products, including some of the important plant nutrients that make up fertilizers.

The use of scrubbers at fossil-fuel-burning power plants has begun to have an impact on the pH of rainfall in many parts of the world, but much more remains to be done to solve the acid rain problem.

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NAME \_\_\_\_\_

DATE \_\_\_\_\_

PERIOD \_\_\_\_\_

## RST - RAIN LIKE VINEGAR

1. Describe three examples of damage caused by acid rain.
2. What is the pH of normal precipitation? How is acid rain defined?
3. What causes normal rain to be slightly acidic?
4. What was significant about a rainstorm in Baltimore in 1981?
5. What are some negative effects of acid rain?
6. The formation of acid rain begins when oxides of sulfur and nitrogen are emitted into the atmosphere. What are sources of these pollutants (list both natural and human sources)?
7. What happens to these pollutants in the atmosphere? What do they form?
8. What is the major source of sulfur and nitrogen oxides? What have scientists developed for these structures that will remove these pollutants?
9. A solution of lime ( $\text{CaO}$ ) is used in a common scrubber. What happens to the sulfur dioxide when it is forced through this solution? What then happens to the product?
10. What does the abbreviation SCR stand for? What pollutant does this device remove?
11. Explain how harmless nitrogen gas and water are formed in the SCR.
12. Scientists are developing a scrubber which will eliminate both sulfur and nitrogen oxides at the same time. What could some of the byproducts be used for?

## Acid Rain

While normal rain has a pH near 6, in some places the pH of rainwater has been measured as low as 3.5. Rainwater with a pH below 5.6 is defined as acid rain- a growing environmental problem in the United States, Canada and elsewhere.

Human activities are the main cause of acid rain. Humans have released many different chemicals into the air. The principal source of acid rain is the burning of fossil fuels. This releases compounds like sulfur dioxide and nitrogen oxides into the air. In particular, coal-burning electrical power plants contribute to acid rain. Coal consists mainly of carbon, but it also contains small quantities of sulfur. When coal is burned, the sulfur reacts with oxygen to form sulfur dioxide and sulfur trioxide. Both compounds react with water in the atmosphere to form acids of sulfur:



Another source of acid comes from the nitrogen gas in the atmosphere. At high temperatures, nitrogen combines with oxygen to form nitrogen dioxide. Nitrogen dioxide reacts with water to form two acids of nitrogen:



Any combustion reaction that produces high temperatures can trigger the formation of  $\text{NO}_2$ . Consequently, automobile engines are an important contributor to acid rain.

### Effects of Acid Rain on living and nonliving things:

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

Quite often, injury or death of trees is a result of these effects of acid rain in combination with one or more additional threats.

Scientists know that acidic water dissolves the nutrients and helpful minerals in the soil and then washes them away before trees and other plants can use them to grow. At the same time, acid rain causes the release of substances that are toxic to trees and plants, such as aluminum, into the soil. Scientists believe that this combination of loss of soil nutrients and increase of toxic aluminum may be one way that acid rain harms trees. Such substances also wash away in the runoff and are carried into streams, rivers, and lakes. More of these substances are released from the soil when the rainfall is more acidic.

Lakes are also damaged by acid rain. A lake polluted by acid rain will support only the hardiest species. When the pH falls below 4.5, very few species can survive. Fish die off, and that removes the main source of food for birds. Also, birds can die from eating "toxic" fish and insects. Acid rain can even kill fish before they are born. Acid rain hits the lakes mostly in the springtime, when fish lay their eggs. The eggs come into contact with the acid, and the entire generation can be killed.

**Metals** and many stone **building materials** can be affected by acid rain. The acidic rain can interact with these materials and wear away or corrode them.

Limestone and marble contain calcium carbonate which readily reacts with acids. Over time the calcium carbonate is separated and gradually washed away leaving behind the worn and altered remains of the statue or building.



1. What is the definition of acid rain?
2. How are the sulfur acids of acid rain formed? (include chemical equations with your answer)
3. How are the nitrogen acids of acid rain formed? (include chemical equations with your answer)
4. How are trees affected by acid rain?
5. What effect does acid rain have on living things in or around a lake?
6. How does acid rain affect nonliving things?