Name _____ Period _____ Article # _____

INVESTIGATING ACID RAIN

(1) Read the accompanying article "Acid Rain," *ChemMatters*, April 1983, pp. 19-21.

(2) Read pp. 478-479 in your textbook, *Glencoe Physical Science*.

(3) Answer the questions below.

Questions (use both the article and the textbook):

1. What is the pH of natural rain? _____ Is natural rain acidic? _____
2. What is the pH range of acid rain/snow? _____
3. Acid rain with a pH of 4.6 is _____ times more acidic than natural rain.
4. List four natural sources of acid rain.

5. When did man-made acid rain first become a problem?

6. What are the major sources of man-made, acid rain causing pollution?

7. What two types of chemical substances are responsible for the formation of acid rain?

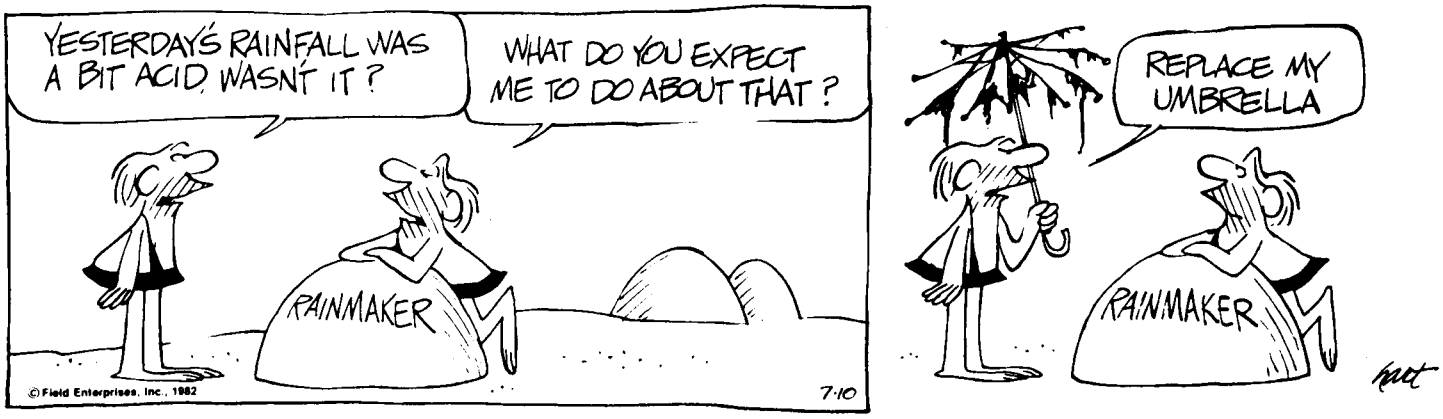
8. In your own words, summarize the effects of acid rain on one of the following – lakes and streams, forests and crops, materials, or human health.

9. What is one method that power plants can use to reduce the emission of acid rain causing pollutants?

(4) Choose a partner and follow the procedure below to simulate the effect of acid rain on sculptures. You will use chalk and vinegar. Chalk is calcium carbonate, the compound that makes up limestone and marble. Vinegar is acetic acid diluted in water.

1. Obtain a piece of waxed paper (about 1 square foot), a piece of chalk, and a paper clip.
2. Use the paper clip to carve a figure from the piece of chalk. Include details such as eyes and hair. Work over the waxed paper to collect the chalk shavings.
3. Place your carving in a beaker or dish. Fill a pipet with vinegar. Let several drops of the vinegar drip onto your work of art. Record your observations on the back of this sheet.
4. Repeat the vinegar treatment five more times. Record your observations each time.
5. Rinse the vinegar down the drain with water and throw your carving in the trash.

B.C. By permission of Johnny Hart and Creators Syndicate, Inc. by johnny hart



What Is Acid Rain?

Acid rain is defined as precipitation that is more acidic than "normal" background precipitation, regardless of its cause—either natural or man-made. The acidity of precipitation can be determined accurately using well-designed analytical procedures, and it has been measured in a number of geographical locations in Scandinavia, Canada, and the U.S. The acidity of rain varies across the continental U.S., generally being higher in the East and lower in the West.

Unpolluted or "clean" rain is always slightly acidic, having a pH of 5.6. This is due to carbon dioxide, which dissolves in water in the atmosphere to produce carbonic acid. Carbonic acid is a weak acid also found in soda water and carbonated soft drinks.

$$CO_2 + H_2O\ (l) \longrightarrow H_2CO_3\ (l)$$
$$H_2CO_3\ (l) \longrightarrow H^+\ (aq) + HCO_3^-\ (aq)$$

Rain or snow is considered "acid" when its pH falls below 5.6. Acidic rain is generally formed by the following steps:

1) Emission into the air of oxides of sulfur and nitrogen, primarily SO_2, NO, and NO_2 from natural and man-made sources.
2) Short- and long-range atmospheric transport of the oxides.
3) A series of chemical reactions between oxides, moisture, and other chemicals in the atmosphere to form sulfuric acid, H_2SO_4, and nitric acid, HNO_3, and others (called the transformation step).
4) Rain or snow carrying the acids to the Earth's surface.

Although scientists agree with this general outline, the exact processes that take place from step one to step four are not clearly understood (see box of uncertainties).

Some people also use the term "acid rain" to refer to the process called "dry deposition," even though rain is not carrying the acid. This occurs when the oxides of sulfur and nitrogen are deposited, or absorbed directly onto surfaces. It is believed that these oxides are then converted into acids after contacting water in the form of rain, dew, fog, or mist, or in the internal structure of plants, which have taken in these particles.

Some Acid Rain Uncertainties

The effects of acid rain were first acknowledged in the 1800s, but only in recent decades have these effects been examined in some detail. There are still many uncertainties associated with the issue. Major gaps in our understanding include the following:

- the pH of precipitation in the absence of human activity;
- evidence of a change in the acidity of precipitation over the past several decades;
- the controlling factors (reagents and processes) in the production of sulfur and nitrogen acids;
- the exact mechanism for oxidizing sulfur dioxide and nitrogen oxides; and
- the relationship between the location(s) of source(s) and the location(s) of the deposition(s).

Some Causes of Acid Rain

Acid rain probably occurred when the first rains fell on our newly formed planet. Volcanic eruptions, forest fires, and bacterial decomposition of organic matter produce sulfur or nitrogen oxides. Lightning bolts form nitrogen oxides from the nitrogen and oxygen gases in the atmosphere.

However, the Industrial Revolution, which began about two-and-a-half centuries ago, started a surge in the amount of man-made pollutants in the atmosphere. Suddenly, sulfur and nitrogen, which had been stored in fossil fuels for millions of years, were released as rapidly as coal could be burned. Today, the major sources of sulfur and nitrogen compound emissions are power-generating plants, ore smelting, petroleum refining, industrial furnaces, and vehicles of all kinds.

In 1980, more than 26 million tons of sulfur dioxide were released into the air in the U.S. In addition, nearly 22

RAIN

million tons of nitrogen oxides were produced. By way of comparison, the eruption of Mount St. Helens in the state of Washington on May 18, 1980, blew out some 400,000 tons of sulfur dioxide, which is just over 1.5% of the total from man-made sources in the U.S. for that same year.

Some Effects of Acid Rain

Lakes and Streams. Most scientists agree that acid conditions affect animals and plants that live in water—in streams, rivers, lakes, ponds, and marshes. The decline in fish population in some rivers and lakes has been linked to the toxic effect of aluminum, which is leached from soil by acid rain. Aluminum compounds collect in the gills of small fish. To combat the pollutant, the fish produce unusually large amounts of a mucus, which eventually strangles them.

A particularly bad time of the year for the aquatic community is spring when the snow melts and runs into streams and ponds. Extensive fish kills in early spring have been attributed to the runoff of the large amount of acid that accumulates on the snow over the winter.

Forests and Crops. Acid rain can dissolve and wash away valuable minerals such as magnesium, calcium, and potassium from the soil. Severe acid rain also can dissolve the waxy covering that protects leaves from fungi and bacteria. It is a well-documented fact that a growing number of forests and crops suffer total or partial damage each year, and there is good reason to suspect that this damage is due, in part, to acid rain. More study is needed to determine the extent to which acid rain is responsible for this damage and to establish the precise cause-and-effect relationship.

Materials. Acid rain is believed to be responsible for many forms of damage to buildings, monuments, and other man-made structures. It is also thought to contribute to metal corro-

WHAT ARE THE CAUSES OF ACID RAIN?

WHY IS ACID RAIN AN INTERSTATE AND INTERNATIONAL ISSUE?

IN WHAT WAY IS THE CONSUMER RESPONSIBLE FOR ACID RAIN?

TO WHAT EXTENT IS ACID RAIN PREVENTABLE?

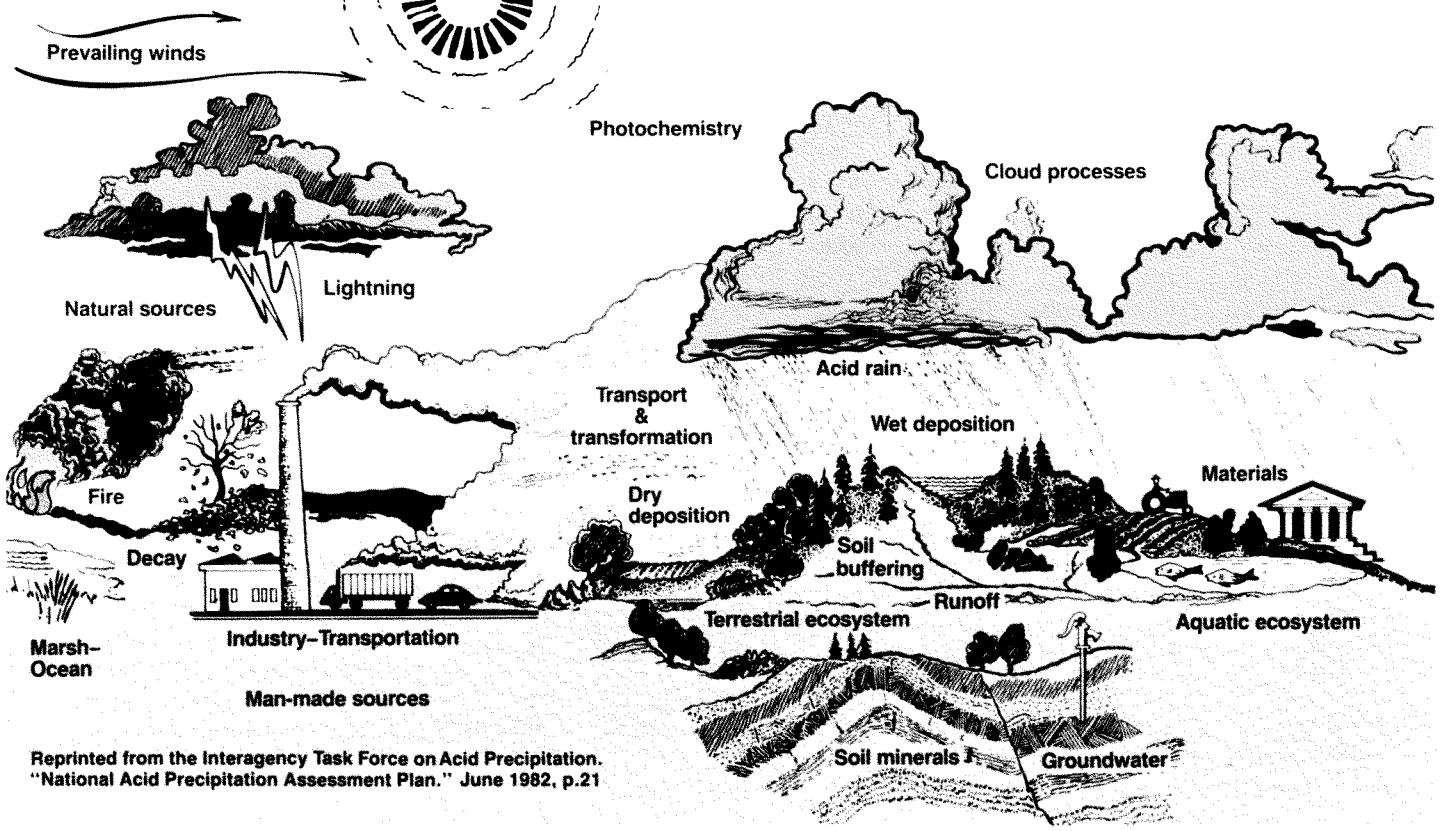


Figure 1. Steps leading to acid rain formation

sion, to reduce exterior paint durability, and to deteriorate textiles, paper, and leather.

Human Health. Little is known about the effects of acid rain on health. There are, however, several reasons for concern. Sulfur dioxide and sulfates are known to be harmful if inhaled, especially by people who suffer from asthma or other respiratory problems. The food chain may also be adversely affected by acid rain. Toxic metals, dissolved by acid rain, may be deposited in waters and finally taken up by fish. In addition, an acidic drinking water supply can dissolve such toxic metals as copper or lead. These metals are often present in the pipes or the pipe joints in plumbing.

No one is absolutely certain about all the effects of acid rain, how serious they are, or what controls are necessary to lessen these effects. Research is currently under way to answer these questions. In the meantime, many scientists are recommending across-the-board pollution emission reductions and are working to find methods of countering the effects of acid precipitation after it has fallen.

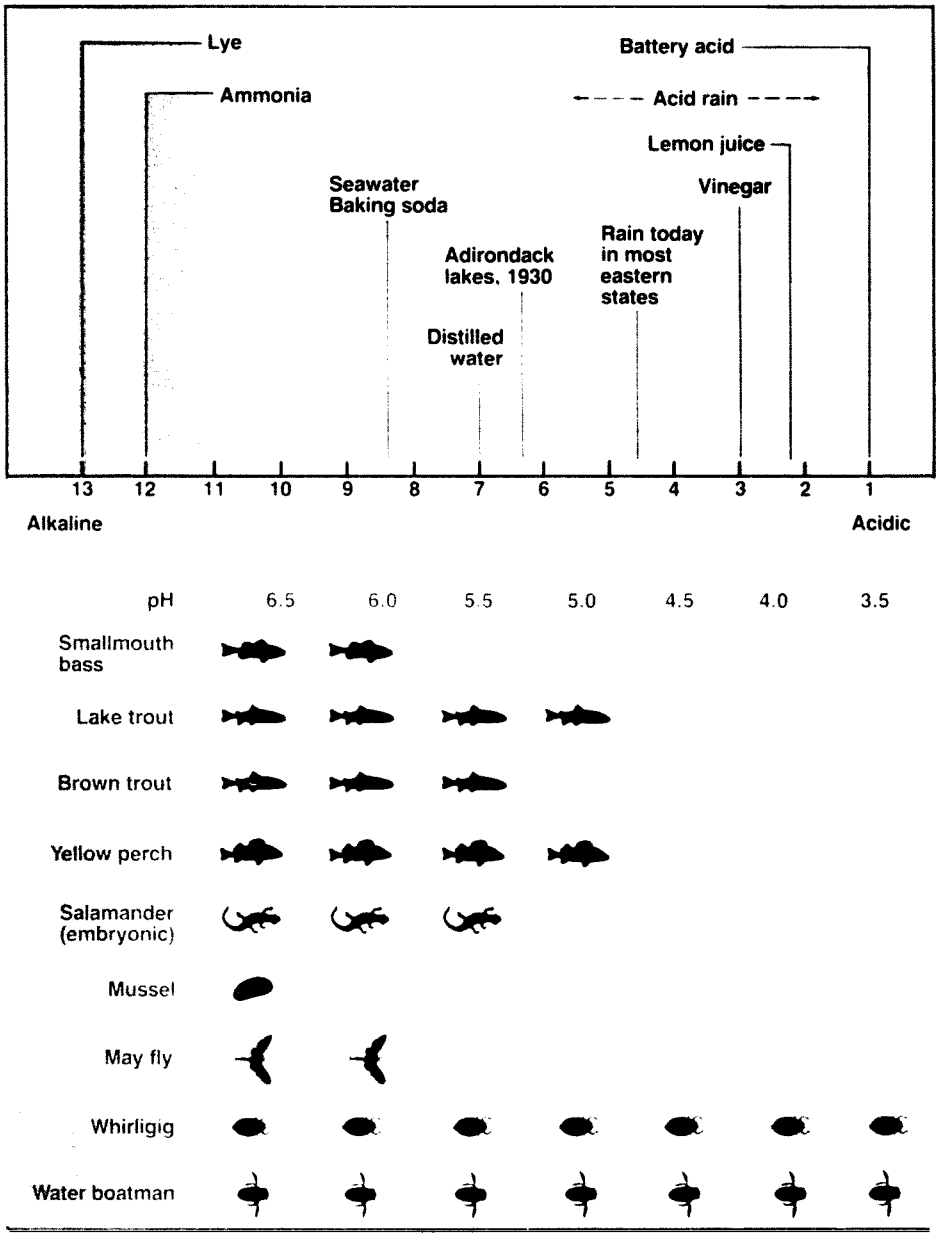


Figure 2. Graph shows acid tolerance of selected fish and invertebrates. Acid rain varies in pH over the approximate range indicated.
(from *The Science Teacher*, also in *National Geographic*—see references)

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A National Acid Rain Survey

Readers who wish to take part in an acid rain survey can do so by sending a self-addressed, stamped envelope to:

The American Chemical Society
Office of High School Chemistry
1155 16th St., N.W.
Washington, D.C. 20036

By return mail, you will receive some pH indicator paper and instructions for its use. Narrow-range pH test strips have been donated by Whatman Paper Division, Whatman Laboratory Products Inc., producer of filter and indicator papers. These strips will be distributed on a first-come, first-served basis and hopefully will furnish your editors with a large number of pH readings of rainfall from a wide geographical area. We plan to share the results of this survey with you in a future issue of *Chem Matters.*

The Rain in Spain

There was a young lady of Spain
Who was angered by acid in rain,
"We must pull up our SO_x
And get rid of NO_x
Or there won't be much left of the plain."

—pHred