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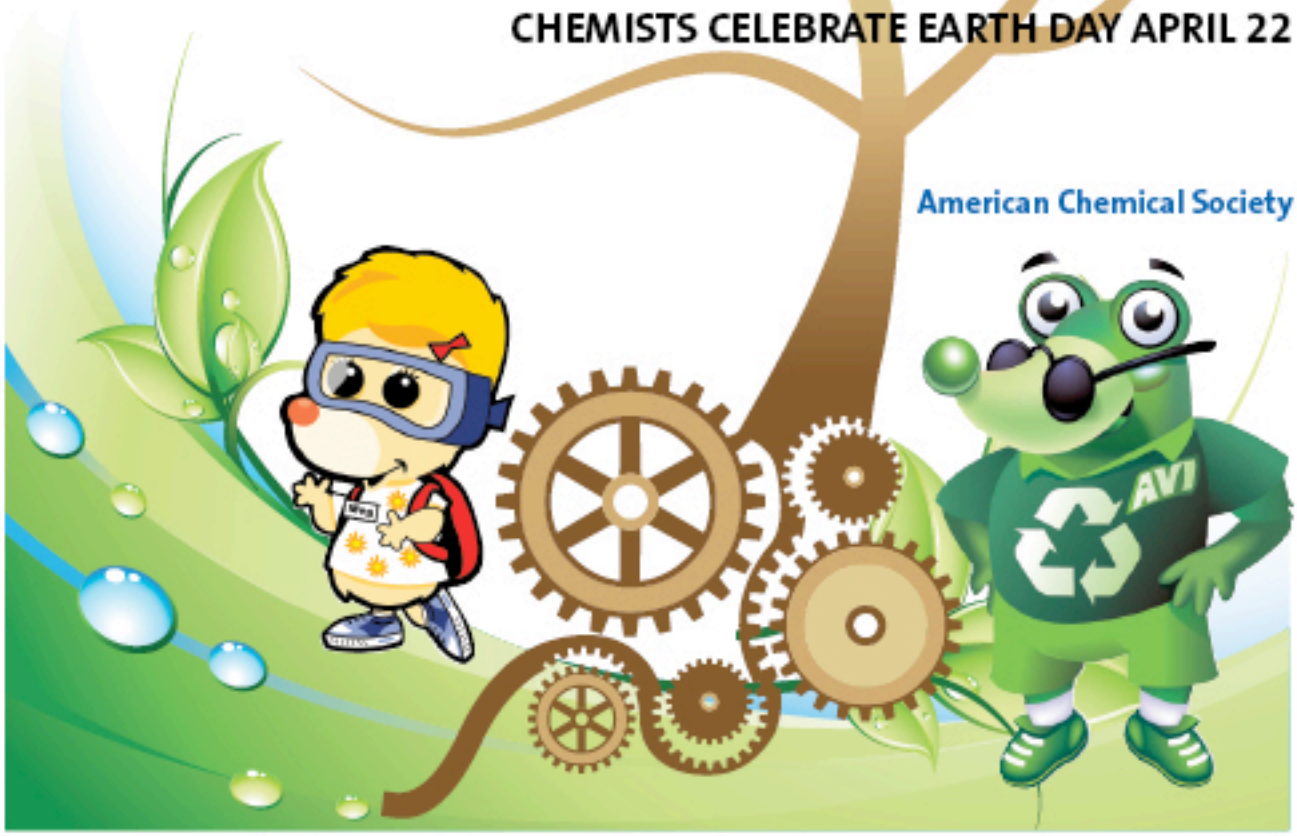
Celebrating Chemistry

Plants – The Green Machines!

CHEMISTS CELEBRATE EARTH DAY APRIL 22



American Chemical Society

Plants–The Green Machines

By Anne Taylor

How can a plant be a machine? Machines are used to make things in factories. Plants—trees, grass, and flowers—just sit there and grow. Plants have a way of making more of themselves, and while they are growing, they make food, energy, and other things that help people.

When you breathe, your body absorbs oxygen (O_2) from the air and gives off carbon dioxide (CO_2). This process is called respiration. In order to grow and function, your body needs food and water (and the minerals and vitamins in the food). Plants are different from animals because they make their own food. Plants take carbon dioxide from the air and make it into all the substances they need. Then they give off excess oxygen. This process is called photosynthesis, which means "putting together with light."

The green substance in plants, chlorophyll, makes photosynthesis possible. Water, sunlight, and minerals are also necessary for photosynthesis. Chlorophyll absorbs the sunlight. Using the energy from sunlight, green plants combine carbon dioxide (from the air) and water to make sugar and oxygen. Green plants use sugar to make starch, fats, and proteins.

Some of the "food" that the plants make eventually becomes cellulose, the building blocks of plant cell walls. The plant builds more cells and becomes bigger and bigger. Thus, these green machines make the food that makes them grow.

This issue of *Celebrating Chemistry* describes some of the amazing things that the green machines do for us humans:

- Plastics that you use almost every day can be made from plants (Plants for Green Chemistry and Plastic, below).
- Plants can be used as a source of energy for cars and homes (Plants–The Energy-Capturing Machines, page 4).
- The first medicines were made from plants. Some still are (Defensive Plants Make Medicines, www.acs.org/earthday).

Scientists have found that excess carbon dioxide is causing the earth to get warmer. If there were more plants, would there be less carbon dioxide and less warming?

Some references

www.ard.usda.gov/is/kids
www.Thinkquest.org

Anne Taylor is a chemistry writer for CTD Quality Consulting and a member of the ACS Committee on Community Activities.

Plants for Green Chemistry and Plastic

By Jennifer Young

One way to describe green chemistry is "doing chemistry the way nature does chemistry." When it comes to plants, they do a lot of chemistry naturally. Green chemistry means doing chemistry in a way that does not pollute the environment or harm humans, and instead, saves energy, makes safer, non-hazardous chemicals, and makes materials that biodegrade or are recyclable.

Plastic does not grow on trees. But scientists have discovered how to make plastics from plants. One way is to make plastic from corn, sugarcane, wheat, or other plants. A new kind of plastic, called polylactic acid (or PLA), is the first plastic made from corn that is now for sale in stores, in the form of beverage bottles, cups, silverware, and food containers. To make PLA, the starch in corn is treated to produce glucose. The glucose is changed into lactic acid, which is then converted into PLA. In the future, PLA and other plastics will be made from plants that we do not eat.

Can you find any PLA plastic bottles, cups, or containers from the grocery store? Look for PLA stamped on the bottom of the container, often along with recycle symbol #7.

Students at Simmons College in Massachusetts have made PLA into a "green" bathroom cleaner, lactic acid, in their experiment called "Cups to Cleaners, Trash to Treasure." To do this, the students collect PLA cups from the cafeteria trash, cut the cups into small pieces, and soak the PLA pieces in acid (vinegar) or base (sodium hydroxide). In the end, they create lactic acid, which they use to wash away soap scum in the bathroom.

Plants–The Green Machines! Word Scramble

Unscramble the words below.

1. tesRapiorn	7. tPlnsluota	13. olelseuCl
2. yllhooCphlr	8. Eyengr	14. arnFtmeinteo
3. nAtoogmris	9. Fssloi Felus	15. Mediecnis
4. ulusypretacmcroHa	10. ssotthoyhensPi	16. rinpsAi
5. cyesPnnesr	11. Bamisso	17. loxTa
6. iomiareethdPyton	12. IfoBuie	18. Aotxiastnndi

Visit **www.acs.org/earthday** for the solutions!

Jennifer Young is a Senior Program Manager for the ACS Green Chemistry Institute®.

Cabbage Chemistry

Introduction

Is it an acid, base, or neutral? Make your own indicator to test various household substances.

Materials

- **Red cabbage**
- **Knife**
- **Blender or food processor**
- **Strainer**
- **Bowl**
- **White coffee filters or white paper towels**
- **Medicine dropper or toothpick**

A series of household items to test:

- **fruit juice: lemon, lime, orange, apple**
- **soda pop (light-colored sodas work best)**
- **vinegar**
- **milk**
- **yogurt**
- **water**
- **liquid cleaning products (don't use bleach)**
- **solution made by dissolving a solid such as baking soda, detergent, antacid tablets, or baking powder in water**

Procedure

1. Chop $^1/_4$ of a red cabbage and place the pieces into a blender or food processor. (To be done with an adult.)
2. Add water until the chopped cabbage is just covered and blend for 1–3 minutes.
3. Place a strainer over a collection bowl and pour the mixture through the strainer to remove the pieces of cabbage. What is the color of the clear liquid?
4. You should have a clear liquid that will be either purple or blue in color.
5. Dip coffee filters or strips of white paper towels into the cabbage juice, then remove them and spread them out to dry. This will be your indicator paper.
6. The color of the cabbage indicator paper will change to red or pink if the solution you are testing is an acid and green or yellow if it is a base. It will remain purple or blue if the test solution is neutral.
7. Next you will test various household solutions. Use a clean toothpick or eyedropper to place a drop of the test solution on the indicator paper. Record the color the drop immediately turns the paper. You can test several different solutions on the same piece of indicator paper.
8. Record the item, the color the paper turns, and if it is an acid, base, or neutral in your data table.

⚠ CAUTION! HEALTH & SAFETY

Be sure to use Milli's Safety Tips, and do this activity with an adult!

Item	Color	Acid/base/neutral
Lemon Juice		
Orange Juice		

Where is the Chemistry?

Substances can be classified according to their properties. Acids are a class of substances that have similar properties because they all contain hydrogen ions. Acids dissolve metals, and they fizz when they react with limestone. Bases are another class of substances that have similar properties. One of the properties of bases is that they react with vegetable oils and fats to make soap. How do you tell if something is an acid or a base? Acids and bases can change the color of some materials called indicators. Indicators can be extracted from many different sources, including the pigment of many plants, such as the red cabbage in this investigation.

Try This...

Other plants can be used to make acid–base indicators, such as red onions, apple skins, blueberries, grape skins, red flowers, and plums. Try this activity using different sources of pigment, to see which produce the best indicators.

Some References

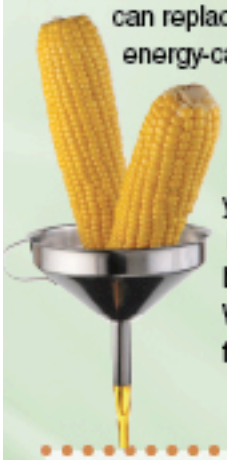
Fun with Chemistry: Volume 1, ed. Sarquis, M., Sarquis, J., Cabbage Patch Detective, Institute for Chemical Education, 1991, Madison, Wisconsin.

Chem Camp Handbook, Institute for Chemical Education, 1992, Madison, Wisconsin.

Plants–The Energy-Capturing Machines

By David Carter and Sharla Wieting

You are probably familiar with what energy is. Energy is the ability to do work. Some type of work has to be done whenever we do anything. Whether we take the bus or walk to school or other places, energy is required. We need electrical energy to power our computers and video game consoles, play music, or to keep our food cold. Most of our energy today comes from chemical sources, especially coal, oil, and natural gas. These energy sources were formed and built up over millions of years from dead plants and animals that were buried and decomposed in the earth. Since they are formed from plants and animals that lived millions of years ago, they are called fossil fuels. We cannot wait millions of years for more fossil fuels to form. More and more we are replacing the use of nonrenewable fossil fuels with renewable energy sources such as solar, wind, and hydroelectrically generated electricity. Nuclear power is another energy source that could provide large amounts of energy long after fossil fuels are gone. A limitation of most of these power sources is that the energy is provided in the form of electricity. Electrical energy is useful for many things, but it is not so useful for traveling long distances. Most electric vehicles have very limited ranges, usually much less than 100 miles. In addition, recharging batteries, unlike filling up the tank at the gas station, takes a very long time. For traveling long distances, it is important that we have energy sources in the form of chemical fuels that can replace gasoline, diesel fuel, and jet fuel. Plants are energy-capturing machines: they use photosynthesis to produce sugars, which are then used to produce other parts of the plants. A large amount of plant material is produced every year when plants grow and then die or are harvested; the portion of this material that can be turned into useful fuel is called biomass. When biomass is changed to fuels, those fuels are called biofuels.



Hydroelectric: Refers to the production of electricity from running water. This electricity is produced when water flowing through dams is used to turn electrical generators.

Fermentation: The conversion of sugar to carbon dioxide and alcohol by yeast in the absence of oxygen.

Man has long known how to use the process of fermentation to convert grains such as corn to ethanol (also known as grain alcohol). Recently, there has been a big push to change corn into ethanol to use in gasoline. However, this is not the best answer. Why? Corn is used for a variety of other things. For one, it is an important fuel source (food) for both man and animals. When corn crops are used to produce ethanol, less is available to the food supply. More people want to buy the corn that is available: some to produce ethanol, some for food, and some to use as animal feed. As a result, the price of corn goes up. The cost of other things will go up as well. Since it costs more to raise animals, the cost of meat and dairy products goes up also. Could there be a better way to produce biofuels than to change corn into ethanol? Biofuels can be made from any biomass. Imagine if all of the grass and weeds that have been mowed along the roadsides and highway medians of your county in the last year were dried, placed in a big pile, and burned. That would be a really big fire and produce a lot of energy! It is possible to make biofuels from these types of materials. However, they contain a high amount of cellulose, the fibrous material of plants that give them structure and strength. Wood and paper are made almost completely of cellulose. Most grains such as corn are made up of starch. It is much more difficult to change cellulose to biofuels than it is to convert starch. Scientists are working to devise methods to convert all sorts of biomass into useful fuels. Plants, the mean, green, energy-capturing machines, may one day be the main source of our transportation fuels.

Interesting fact: Biomass (3.5% of U.S. energy usage) is already a greater source of energy in the United States than hydroelectricity (2.5%) (http://tonto.eia.doe.gov/energy_in_brief/renewable_energy.cfm).

David Carter is an Assistant Professor of Chemistry at Angelo State University, San Angelo, TX and a former member of the ACS Committee on Environmental Improvement.

Sharla Wieting is a science instructor at McGill Elementary School in San Angelo, TX.

Paper Chromatography with Leaves

Introduction

Most plants contain several pigment molecules. In this activity, you will use different leaves to see the wide range of pigments.

Materials

- Leaves
- Baby food jars with lids
- Rubbing alcohol
- Coffee filters
- Hot tap water
- Shallow pan

Procedure

1. Take 2–3 large leaves (or the equivalent with smaller leaves), tear them into tiny pieces, and place them into the baby food jars with lids.
2. Add enough alcohol to just cover the leaves.
3. Loosely cover the jars with the lids and set them into a shallow pan containing an inch or so of hot tap water.
4. Let the jars sit in the hot water for at least half an hour. Replace the hot water as it cools and swirl the jars from time to time.
5. The jars are "done" when the alcohol has picked up color from the leaves. The darker the color, the brighter the chromatogram will be.
6. Cut or tear a long strip of coffee filter paper for each jar.
7. Place one strip of paper into each jar, with one end in the alcohol and the other outside of the jar.
8. As the alcohol evaporates, it will pull the pigment up the paper, separating pigments according to size (largest will move the shortest distance).
9. After 30–90 minutes (or until the desired separation is obtained), remove the strips of paper and allow them to dry.
10. Can you identify which pigments are present?
11. How do you think change in seasons will affect the colors of the leaves?

Where is the Chemistry?

Most plants contain several pigment molecules; some chemists experiment with different leaves to see the wide range of pigments. Chemists use a process called chromatography to separate and identify pigments and other molecules within plants. The solubility, the size of particles, and their attraction to the paper are all involved in the separation of the colors.

Try This...

Use frozen, chopped spinach leaves and see whether the results differ from those of tree leaves. Use other types of paper to see how much of the pigment is absorbed.

Milli's Safety Tips Safety First!

ALWAYS:

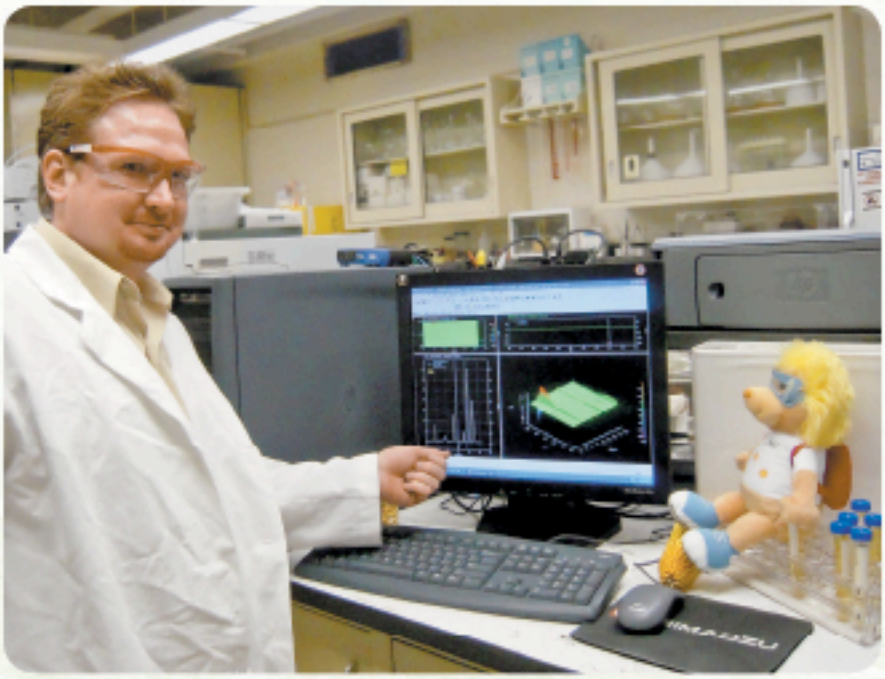
- Work with an adult.
- Read and follow all directions for the activity.
- Read all warning labels on all materials being used.
- Use all materials carefully, following the directions given.
- Follow safety warning or precautions, such as wearing gloves or tying back long hair.
- Be sure to clean up and dispose of materials properly when you are finished with an activity.
- Wash your hands well after every activity.

Never eat or drink while conducting an experiment, and be careful to keep all of the materials away from your mouth, nose, and eyes!

Meg A. Mole Celebrates Earth Day!

Meg Interviews Chemist Michael Appell

In honor of this year's Chemists Celebrate Earth Day, I went to visit Michael Appell at the National Center for Agricultural Utilization Research in Peoria, Illinois! Dr. Appell works for the U.S. Department of Agriculture, Agricultural Research Service (ARS). The ARS is the U.S. Department of Agriculture's chief scientific research agency. According to Dr. Appell, their job involves "finding solutions to agricultural problems that affect Americans every day, from field to table."



I asked Dr. Appell to tell me more! What does that mean, and how is it related to our Earth Day theme? Dr. Appell explained that he "uses chemistry to try to find new ways to improve the value of agricultural commodities" and that "a major focus of his research is food safety." Food safety is definitely important for this little mole! I want to make sure all of the plants I eat are safe for me, too! Dr. Appell also works on projects to "find new uses for bio-based materials."

Dr. Appell uses many different types of equipment to do this type of chemistry, including "chemical glassware to create new materials, very fast computers to assist understanding the properties, and sophisticated analytical instruments for detection." To make sure he is safe when he does his work, he wears special gloves, safety glasses, and a lab coat! I enjoyed trying on his gloves, but they were a little too big for me!

When asked what he likes best about being a scientist, Dr. Appell told me he liked the "sense of accomplishment associated with contributing to solving agricultural problems using chemistry and the excitement of scientific discovery." Also, he likes the opportunities he has "to work with fellow scientists to find solutions to problems. Science provides opportunities to work with people from around the world to solve problems."

Credit: Michael Appell

Dr. Appell told me that he was very interested in art when he was growing up. His interest in science also started because he grew up on a farm! He belonged to his local 4-H youth club (**http://4-h.org**). Those activities "provided many opportunities to practice the important methods of science outside of the classroom, such as project management, documenting results, establishing cause and effect, and problem solving."

So how does his work impact everyone, and where does a child come in contact with his work? Dr. Appell explained that "chemistry plays an important role in food and agriculture, especially in the cooking and preparation of food. Flavors are a great way to experience chemistry. An example is the toasting of bread. The rich toast flavor is produced during toasting by chemical reactions between sugars and the components of proteins. The difference in the taste of bread and toast is chemistry."

Personal Profile:

Michael Appell

What is your favorite color? Blue

When is your birthday? January 4

Favorite pastime? Touring the countryside on motorcycles with family and friends.

About your family: My wife, Melissa, and I are always looking for new experiences and adventures to share.

Photosynthesis and Transpiration

Introduction

Examine the effects that light and air have on green plants.

Materials

- **Two planting containers**
- **Seeds (lima beans, peas, broad beans)**
- **Soil**
- **A dark area and a bright area**
- **Glass bottle or jar**

Procedure

1. Give the seeds a little head start by soaking them in water overnight.
2. Plant 5 seeds in each container.
3. Place one container in a dark place and the other in a bright place.
4. Keep the seeds in their places for a week, watering them when the soil gets dry.
5. After this time, remove the seed from the dark place and compare it to the one placed in the bright place. What differences do you see?
6. Remove one seedling from each container, and compare the root systems.
7. Take the seedlings that **did not** develop and place them in a bright place. Record any changes.
8. Take the seedlings that **did** develop and place them in a bright place with a clear bottle or jar on top of them, and record any changes.
9. After 1 day, record all the changes you observed.

Where is the Chemistry?

Photosynthesis is the process by which plants convert light energy from sunlight into chemical energy (glucose). Carbon dioxide, water, and light are used to make glucose and oxygen. Transpiration is the evaporation of water from trees into the Earth's atmosphere. Transpiration takes place in this activity when water vapor is emitted by the plant when it exchanges oxygen for carbon dioxide. Leaf transpiration occurs through pores called stomata with a loss of some of its valuable water. Stomata are designed to allow the carbon dioxide gas exchange from air to assist in photosynthesis.

In this activity, condensation will collect on the inside of the bottle or jar overnight. This is the water vapor that is emitted by the plant when it exchanges oxygen for carbon dioxide, which is called transpiration.

Plants–The Green Machines! Word Search

A	T	T	A	Y	P	L	S	P	N	N	A	U	L	S	R	C	D
L	L	H	M	F	O	S	S	I	L	F	U	E	L	S	E	F	V
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H	Y	P	E	R	A	C	C	U	M	U	L	A	T	O	R	S	R
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C	T	E	A	S	E	G	B	U	I	O	K	K	I	G	T	T	Y
D	C	R	T	H	U	J	K	I	G	A	S	P	I	R	I	N	L
P	S	L	O	C	F	U	E	I	L	L	H	Y	P	E	D	T	L
R	T	G	Y	U	H	F	T	A	N	T	S	G	J	G	R	E	Z

Agronomist
Antioxidants
Aspirin
Biofuel
Biomass
Cellulose
Chlorophyll
Hyperaccumulators
Medicines
Photosynthesis
Phytoremediation
Pollutants

Go to **www.acs.org/earthday** for the solution.

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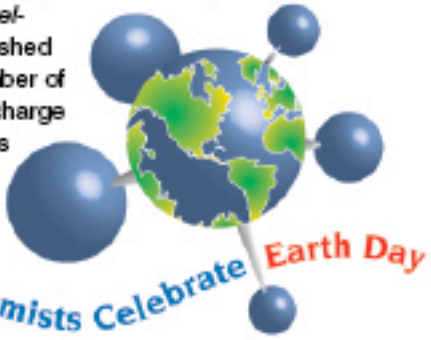
CCED 2010 "Plants–The Green Machines!" Glossary

1. **Agronomist:** A person who studies agriculture dealing with field-crop production and soil management.
2. **Antioxidants:** A chemical compound or substance that limits reactions promoted by oxygen.
3. **Aspirin:** A white crystalline derivative tablet of salicylic acid used for relief of pain and fever.
4. **Biofuel:** A fuel composed of or produced from biological raw materials.
5. **Biomass:** Plant materials and animal waste used especially as a source of fuel.
6. **Cellulose:** The principal part of the cell walls of plants.
7. **Chlorophyll:** The green photosynthetic pigment found mainly in the chloroplasts of plants.
8. **Fossil fuels:** A fuel formed in the earth from plant or animal remains.
9. **Hyperaccumulators:** Plants that take up and accumulate metals from the environment.
10. **Medicines:** Substances used to treat a sickness or disease.
11. **Photosynthesis:** Formation of carbohydrates from carbon dioxide and a source of hydrogen in the chlorophyll-containing tissues of plants exposed to light.
12. **Phytoremediation:** Using plants and trees to clean up soils or water.
13. **Pollutants:** Waste material that contaminates or makes another substance dirty or not pure.

Celebrating Chemistry: Earth Day Edition!



The Earth Day Edition of *Celebrating Chemistry* is published annually, and a limited number of copies are available at no charge through your local Chemists Celebrate Earth Day Coordinator and the American Chemical Society (ACS). Chemists Celebrate Earth Day is a combined effort among the Office of Community Activities, the Committee on Community Activities, and several ACS Technical Divisions. Please visit **www.acs.org/earthday** to learn more.

What is the American Chemical Society?

The American Chemical Society (ACS) is the largest scientific organization in the world. ACS members are mostly chemists, chemical engineers, and other professionals who work in chemistry or chemistry-related jobs. The ACS has more than 161,000 members. Most ACS members live in the United States, but others live in different countries around the world. Members of the ACS share ideas with each other and learn about important discoveries in chemistry during meetings that the ACS holds around the United States several times a year, through the use of the ACS website, and through the journals the ACS publishes.

The members of the ACS carry out many programs that help the public learn about chemistry. One of these programs is the Chemists Celebrate Earth Day, held annually on April 22. Another of these programs is National Chemistry Week, held annually the fourth week of October. ACS members celebrate by holding events in schools, shopping malls, science museums, libraries, and even train stations! Activities at these events include carrying out chemistry investigations and participating in contests and games. If you'd like more information about these programs, please contact us!

Knowledge Check-Up

Cabbage Chemistry

- Are household cleaners usually acid, base, or neutral?
- Is soda pop an acid, base, or neutral?

Paper Chromatography with Leaves

- What is the process called to separate and identify pigments and other molecules within plants?
- Did you use hot or cold water in this activity?

Photosynthesis and Transpiration

- Carbon dioxide, water, and light are used to make what?
- At what point does transpiration take place in this activity?

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