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Celebrating Chemistry

National Chemistry Week — American Chemical Society

Colors of Light–Nature's Paint Box

By Marilyn Duerst

Look out the window at the world outside – how many different colors can you see? You might see bright yellow sunflowers, red roses, and green grass. An orange-and-black monarch butterfly might be flitting among the purple irises. If you have a vegetable garden, you might see red tomatoes, or orange pumpkins that are fun to carve into scary faces on Halloween. The leaves on the trees may have turned to brilliant reds, yellows, or oranges.

Did you ever wonder why flowers, fruits, grass, insects, rocks, and bird feathers have color? Or have you wondered the same about the colors in sunsets, crayons, paint, or T-shirts?

Maybe you know that the primary colors of paint and ink are red, yellow and blue — and that purple, orange, and green — or even black — can be made from mixtures of these colors. But you might be surprised to learn that light is very different. The primary colors of light are red, blue, and green, and mixed together they make white light!

Light from the sun or from ordinary light bulbs is sometimes called "white light," but this type of light really consists of all the colors of the rainbow. If you are lucky, you have seen a real rainbow. If the sun is behind your back and "white" light from the sun hits tiny droplets of water that are still in the air at just the right angle, those colors can bend and spread out in a curved shape. Bubbles, peacock feathers, and opals also can bend light and create multi-colored light effects.

If you have ever explored a cave when the guide turned off all the lights, or have been in a totally dark room, you probably saw absolutely nothing. Light from some source must shine on objects so we can see them. Colored objects all around us contain tiny molecules called **pigments** or **dyes** that can absorb (soak up) some of the colors of light, that hit them, and bounce the other colors back to our eyes. For example, grass and leaves look green because the **chlorophyll** molecules in them can absorb all the colors of light that hits them except green, which bounces off and hits our eyes.

In this issue you will learn about how to do some experiments with light and artificial and natural dyes. Have fun with our colorful experiments!

Marilyn Duerst *s a retired Distinguished Lecturer in Chemistry at the University of Wisconsin-River Falls. She has taught K-12 teachers and college students there for 34 years, where her nickname is "Mrs. Wizard." She collects sand, minerals, and bird sculptures from all over the world, and has an element collection.*

Fireworks— Going Out in a Blaze of Color!

By Al Hazari

What do table salt, laundry borax, and white chalk powder have in common? When they are put in a fire, these household chemicals produce special colors of flame. Yellow-orange flames appear with table salt (**sodium chloride**), green-blue flames with laundry borax (**sodium borate**), and brick-red with white chalk powder (**calcium carbonate**). This is the basis of the colorful displays in fireworks. But of course, fireworks are more than colors. There are also bright sparkles and loud bangs ("kabooms"), complete with their own fascinating chemistry stories.

The art of making fireworks is called **pyrotechnics**. But what are fireworks made of, and why they behave the way they do? The idea of mixing chemicals to produce explosives and fireworks dates back more than a thousand years, and probably first happened in what is now China. Today's fireworks work by burning chemicals to produce motion and special visible or audible effects.

A typical fireworks mixture consists of a metallic fuel, along with chemicals called **oxidizers** that make the fuel burn. The mixture is bound together, then cut into flammable pieces called stars. The stars are the colored dots that burst from a fireworks shell into the sky. The shell is launched from a steel cylinder using black powder as the **propellant** that makes them shoot up into the sky. Recipes for making stars are numerous … but there are only a handful of the 118 known chemical elements (mostly metals) that give off a color when burned. **Iron** produces a gold color, while **magnesium** produces bright white, **strontium** produces red, and **copper** produces blue. Just as an artist mixes paint, firework makers can mix different elements to produce other colors. For example, mixing strontium and copper gives a purple color.

Let us safely enjoy the next bright and multi-colored celebration that may be followed by loud noises coming from an outdoor fireworks show in our neighborhood. Remember, it may look like magic, but it's simply "colorful chemistry" at work!

Al Hazari, Ph.D., *is the Director of Laboratories and a Lecturer in Chemistry at the University of Tennessee, Knoxville. He is involved in science and chemistry outreach for everyone.*

Where to Find More Information

http://fireworkssafety.org
http://pubs.acs.org/cen/whatstuff/stuff/7927sci3.html
http://www.pbs.org/wgbh/nova/kaboom

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 warnings 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!

NEVER experiment on your own!

Why is the Sky Blue and the Sunset Red?

Do you have any idea why the sky usually appears blue, especially in the middle of the day, and the sunrise and sunset often are red or orange? One hint about the answer is that at sunset or sunrise, the sunlight we observe has traveled a longer distance through the atmosphere than the sunlight we see at noon.

To see how this happens, let's pretend that a pitcher or glass filled with water and a little milk is like earth's atmosphere. Then we'll experiment by seeing what happens when light passes through it at different angles.

Materials:

- **Clear glass pitcher or tall glass with straight sides**
- **Milk**
- **A 3″ x 5″ or 4″ x 6″ white index card**
- **Flashlight**

SAFETY SUGGESTION:
Do not taste and materials used in this experiment.

Disposal: All materials used in this experiment can be safely disposed of down the drain with running water.

Procedure:

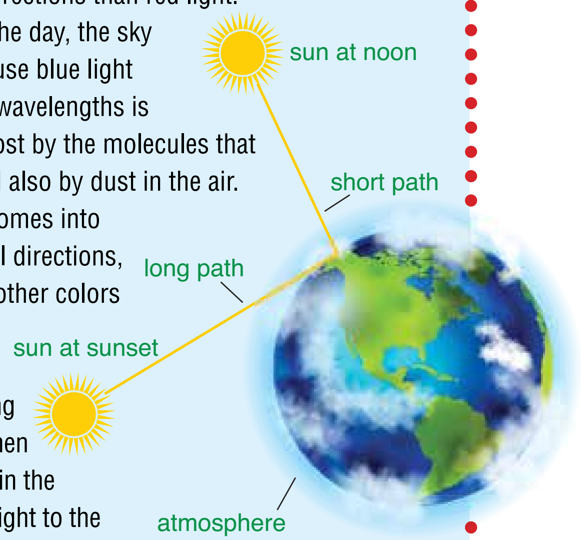
1. Fill a clear glass pitcher or tall glass about 3/4 full with water.
2. Add a few drops of milk and stir until the mixture is slightly cloudy.
3. Darken the room and turn on the flashlight.
4. Shine the flashlight beam through the pitcher or glass from the side. What color is the beam of light, if you look at it from the side?
5. Now hold a white index card at the opposite end of the pitcher or glass from the flashlight, so that the flashlight beam strikes the card. Does the light from the flashlight still look white, or is it a different color?

For a different experiment, shine the flashlight beam up from the bottom, look down into the glass and see if the color of light is still white.

Where's the chemistry?

"White" light consists of all the colors of the rainbow, from violet to blue, green, yellow, orange, and red. Blue and violet light have shorter **wavelengths** than red and orange light, and are much more easily scattered and reflected in all directions than red light.

For most of the day, the sky looks blue because blue light with its shorter wavelengths is scattered the most by the molecules that make up air, and also by dust in the air. This blue light comes into our eyes from all directions, dominating the other colors that are in light from the sun. But in the evening and morning, when the sun is lower in the sky, the path of light to the viewer from the sun travels through a longer distance in the atmosphere, so most of the blue and violet light has been scattered, leaving mostly yellow, orange, and red light that comes to our eyes.



As light passes through the milk/water mixture, the shorter wavelengths (blue and violet) scatter in many directions — even sideways to your eyes. This may give the light beam a bluish tint. The light at the top of the drinking glass (or at the opposite end of the pitcher or tall glass) consists mostly of the red and orange wavelengths. This is because they were not scattered as much, and were able to get all the way though the water.

Diagram from: http://scifun.chem.wisc.edu/homeexpts/bluesky.html

Natural Dyes and Pigments from Bugs, Shellfish and Rocks

By Verrill M. Norwood

Think about your clothing — are some pieces brightly colored? The bright colors come from colorants (substances that provide color) used in a process called **dyeing**. Have you ever had your face painted? The color in face paint comes from colorants called **pigments**. Many colorants that are used today are man-made, which means they are **synthetic**, and were not available until about 150 years ago. What did people use as colorants before the synthetic ones became available?

Colorants from natural sources such as rocks, plants, and shellfish have been used for thousands of years. The most important yellow dye in ancient and medieval times was called **weld**, which comes from the seeds, stems, and leaves of a wildflower known as dyer's rocket. In combination with the blue dye called **woad**, which was similar to **blue indigo**, it was used to produce the green made famous by the legend of Robin Hood and his Merry Men.

The source of the intense red color called **carmine** comes from crushed female **cochineal** insects (pronounced co-chi-neel) found in Mexico and Central and South America that feed on prickly pear cactus. Those insects were an important export product from the New World back to Spain, and cochineal-laden ships were the prime targets of pirates on the high seas!

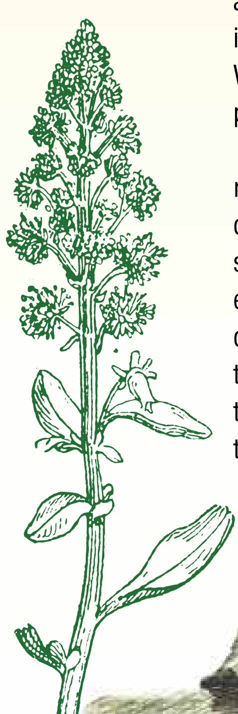
Purple was called a "royal color" because it was very rare in nature and expensive to make. The earliest purple dyes date back to about 1900 B.C. It took about 10,000 shellfish to extract just one gram of the pure dye … barely enough to color a single Roman toga! This special purple dye, known as Tyrian or "royal" purple, was worth more than gold! It's no wonder that this color was only allowed to be used for clothing worn by the Roman emperors and the Egyptian pharaohs.

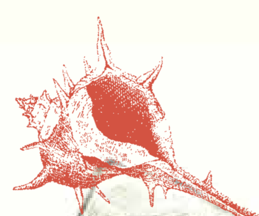
The earliest known natural pigments, used as colorants for paints and inks, came from a special kind of dirt called **"iron earth"** (red, yellow, or brown) or a black mineral called **manganese dioxide** (MnO_2). Those colorants are found in prehistoric cave paintings in southern France.

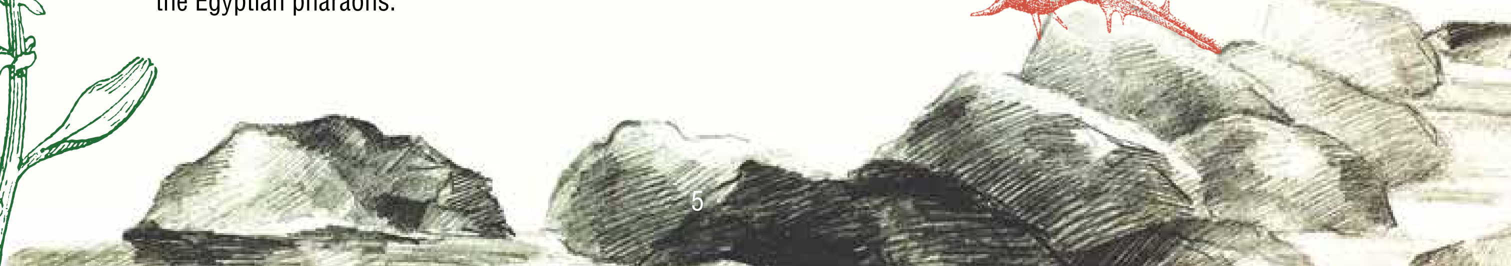
Natural ultramarine blue was one of the most expensive and desirable of the natural blue pigments. Europeans called it **ultramarine**, a Latin word meaning "beyond the sea." They called it this because its only known source until the nineteenth century was on the other side of the Caspian Sea, in the very remote caves of Badakshan in Afghanistan. Ultramarine blue was first introduced to European artists in the thirteenth century, after Marco Polo returned to Italy following his spectacular journeys in Asia.

Some natural pigments that have been in use since pre-historic times contain **heavy metal elements** like **arsenic** (As), **mercury** (Hg), and **lead** (Pb), that are harmful to human health. An arsenic-containing pigment called **orpiment** is bright yellow and has the formula As_2S_3. Orpiment has been found on wall paintings in Giza (Egypt) as early as 4000 B.C. **Vermillion** (HgS) obtained from the mineral **cinnabar** has been used since Roman-times as a red pigment. Amazingly, vermillion was used until the late 19th century to color foods red so that children would find them more attractive to eat!

***Verrill M. Norwood, Ph.D.,** is an Assistant Professor of Chemistry at Cleveland State Community College.*







Chemistry

- **Indigo** dye for turning jeans or overalls dark blue originally came from the dried leaves of plants that grow in *India*, which is how the dye got its name.

- Roses are red because their petals contain pigments called anthocyanin that reflect red color into our eyes, and absorb all the other colors of light. Anthocyanin in plants can also reflect red, purple or blue color, depending on the pH of the soil the plants are growing in. Some flowers, like irises, contain **magnesium** along with anthocyanin, giving them a blue color.

- Pumpkins and carrots are orange because they contain a dark orange pigment called **beta-carotene**, which is named after carrots. Red tomatoes contain **lycopene**, and yellow corn contains **lutein**.

- Butterflies often show intense, multicolored, **iridescent** colors when light reaches tiny air spaces in their wings. The colors change as the butterflies move. Some seashells, opals, and peacock feathers also are iridescent.

- If you are lucky, you might see a rainbow when the sun is behind you and “white” sunlight is bent into all the rainbow colors by **refracting** through microscopic water droplets in the air.

- Grass and other plant leaves are green because several green compounds called **chlorophylls** allow the plants to absorb the light energy they need from the sun to make their own food. This process is called **photosynthesis**.

- Crushed, colored rocks have been used for thousands of years as pigments in paint, especially **iron oxides** that are yellow, orange, red, brown, or black.

Colors Our World

Food Colors

By Ronald P. D'Amelia

Nature has given us fruits and vegetables with a rainbow of colors. For fun, try listing some of nature's fruits and vegetables that have unique colors. To help you start, think about red apples and tomatoes, orange pumpkins, yellow bananas and squash, green lettuce, and purple grapes. Here's a strange fact: except for blueberries, there are not many naturally blue foods. Even the colorants called **anthocyanins** (which can make a plant reflect red, purple or blue color, depending on the pH of the soil it is growing in) look reddish-purple when the juice is squeezed out.

Since we all like colorful food, almost everything found in a modern grocery store has some color added to it, including "mac and cheese," margarine, soda pop, snack foods, candies, and birthday cake frosting.

Food colors can be either "artificial" or "natural." **Beta-carotene** (from carrots) is a natural colorant added to margarine; some vegetable colors are used in beverages, but most of the colorants in prepared foods are artificial. These compounds have been tested over many years to make sure they are safe to eat, and every batch of artificial food color must be certified as safe by the Food and Drug Administration, a part of the United States Government. Only seven dyes can be used in foods: Red 3, Red 40, Yellow 5, Yellow 6 (which looks orange), Blue 1, Blue 2 and Green 3. Sometimes these color names have the letters "FD&C" in front of them.

If you look at a package of colored candies, you might find "Red #40 lake." This kind of "lake" is not a place you can go fishing or canoeing! This lake is actually dye wrapped up inside an aluminum compound, so the color does not come off on your hands or clothing as easily.

Ronald P. D'Amelia, Ph.D. *retired from Kraft/Nabisco as a senior Principal Scientist after 32 years of service. He is currently an Adjunct Professor of Chemistry at Hofstra University, the Faculty Advisor to the Hofstra chapter of student members of ACS, and a Fellow of the ACS.*

A Color-Changing Liquid

By Marilyn Duerst

Let's do some experiments with a natural food colorant in many kinds of berries and flowers, called "anthocyanin." Some of these colorants actually change color if they are mixed with an acid or base, just like some flowers look pink or blue depending on the soil in which they're growing.

Materials:

- **Blueberry syrup, juice, or smashed blueberries**
- **3 small bowls**
- **Measuring spoons**
- **Fork**
- **Powdered dishwasher detergent or cleanser**
- **Clear soda pop or vinegar**
- **Baking soda**

Procedure:

1. If you have fresh blueberries, smash about 12 in a bowl with a fork. Add about a tablespoon of water and stir. What color is the water? Scoop out the solid parts and throw them away. If you have blueberry juice or syrup, just keep it handy.
2. Arrange 3 small bowls in a row.
3. Pour about 1 teaspoon (tsp.) water into each bowl and $^{1}/_{4}$ tsp. blueberry juice or blueberry syrup. Stir carefully. What color is the liquid? ______________________
4. Add about 1 tsp. powdered dishwasher detergent or a white, powdered "cleanser" to the liquid in one bowl and stir carefully. Did the color change?
5. Add about 1 tsp. baking soda to the liquid in another bowl and stir carefully.
   Did the color change?
6. Add about 1 tsp. clear soda pop or vinegar to another bowl and notice the color change.
7. Try other household materials with your parent's help.

SAFETY SUGGESTIONS

- **Do not taste any materials used in this activity.**
- **The berry juice can stain your hands.**
- **Wash with soap and water at the end of this activity.**
- **Wear safety splash goggles.**

Disposal: All materials used in this experiment can safely be disposed of down the drain with running water.

Where's the chemistry?

Blueberry juice contains a substance called anthocyanin that changes color depending on whether it is mixed with an acid or a base. Chemists call it an "acid-base indicator." Blueberry juice normally turns red or pink in an acid, blue in a mild base, and green in a more strongly basic solution (like dishwasher detergent).

Word Search

Try to find the words listed below — they can be horizontal, vertical or diagonal, and read forward or backward!

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

ANTHOCYANIN	IRIDESCENT	PROPELLANT	VISIBLE SPECTRUM
CHLOROPHYLL	MAGNESIUM	PYROTECHNICS	WAVELENGTH
COLORANT	PIGMENT		

The Adventures of Meg A. Mole, Future Chemist

Nancy M. Hepp
Color Chemist

As part of this year's "Chemistry Colors Our World" National Chemistry Week celebration, I traveled to the US Food and Drug Administration, where I met Nancy Hepp, a color chemist! Dr. Hepp's job is to "test and evaluate the safety of colors that may be added to foods, drugs, cosmetics, and/or medical devices." She discovers different ways to "test for and measure amounts of certain harmful substances that may contaminate colors."

My first stop was to visit the laboratory where Dr. Hepp does some of her work. She explained it was very important to be safe in the laboratory. She wears a lab coat, just like a medical doctor, as well as gloves and goggles! I asked what she enjoys most about her job. She explained that "she loves that she doesn't have to sit still!"

She also likes solving the puzzles that come up every day, like fixing problems with instruments and trying different ways to do experiments. "For example, sometimes I try using different amounts or types of chemicals, or changing reaction times or temperatures, to see if I get better results." She enjoys "making tables and graphs to see a lot of information… all in one picture!" Another thing she gets to do is "learn about new products, like iridescent and sparkly colors used in icing, cereal, or candy."

So what does she enjoy most about being a scientist? "There are many great things about being a scientist," she said. "I get to operate lots of different kinds of machinery and instruments. I can wear sneakers, listen to music, and be my own quirky self while I do my work in the laboratories. And at the end of the day, I feel appreciated for doing something meaningful. I know that I helped make sure that the colors you are eating in your food are safe."

Growing up, Dr. Hepp was very interested in science. She remembered that her older brother received presents of chemistry sets and electronic kits — things that she wanted, too! She was fascinated and inspired by the smells, noises, and colored smoke her brother made. She says she "enjoyed pretending to be a 'mad scientist,' but did most of my chemistry in the kitchen with food or household products."

She also told me about some experiments she tried out: "I remember once laughing uncontrollably when my friend and I discovered that water didn't mix well with baby powder, but instead formed little water beads that 'ran around' and scattered away from each other! We also had great fun trying to make the best glue using foods like egg white or flour and water." Some of the classes she enjoyed the most were math, chemistry, and physics.

Dr. Hepp's work is not only fun, but is very important for all of us! The next time you eat candy or put on lip balm, just think about Dr. Hepp and her fellow chemists, who spend their days testing the colors that go in these and other products to make sure they are safe!

Personal Profile

FAVORITE HOBBIES AND INTERESTS:
"I like to cook and garden, which involves more experimenting! I am also very involved in Special Olympics. I love to see people with disabilities who have that same determination that I had as a kid, when people didn't think I could become a chemist."

ACCOMPLISHMENT YOU'RE PROUDEST OF:
"Making reliable methods that help ensure the safety of colors which are added to foods, cosmetics, and other products we use in our daily lives."

ABOUT YOUR FAMILY?
"I love skiing with my two sons, who are now almost adults."

* *Meg A. Mole was developed by the American Chemical Society, Office of Community Activities and written by Kara Allen.*

Is Black a Color?

Have you ever wondered why black T-shirts, black crayons, and black marking pens look “black”? Maybe you know that red T-shirts can reflect red light, and green T-shirts can reflect green light, so black T-shirts must reflect NO light. Let’s investigate a variety of black markers, and find out why they look “black.”

Materials:

- **5 different brands of black markers, both “water-soluble” and “permanent”**
- **5 round, flat coffee filters**
- **Jar, glass, cup or jar lid (such as from a peanut butter jar)**
- **Water and an eyedropper**

Procedure:

1. Lay a flat coffee filter on a flat surface. Choose one of the marking pens and color a solid circle in the center, about ½ inch (about 1 cm) across. With a pencil, label the filter paper with the brand of the marker you are using.
2. Lay the coffee filter over the top of the jar.
3. Drop water onto the center of your black dot. Use 5 to 10 drops, but do so slowly.
4. Observe what happens when the first drop of water hits the black dot, and when you add more drops. What happens to the black dot and its color?
5. Repeat with the other pens on the other coffee filters.
6. Fill out the data table with what you observed for each brand of marker.

SAFETY SUGGESTION:

There are no safety hazards with this experiment.

As with any science experiment, eye protection should be worn. In this particular experiment, safety glasses will be sufficient.

Where’s the chemistry?

Ancient inks were made with finely-crushed charcoal mixed with sticky liquids from plants called **resins**. Modern black inks in marking pens are usually mixtures of a variety of colored inks mixed with different liquid solvents. In this experiment, as the water moves across the paper by a force called **capillary action**, some parts of the ink (components) are carried further than others. Different brands use different combinations of ink to produce their “black,” so each brand separates into its own color pattern.

The original question was, “Is Black a Color?” Each of the colored components in a “black” ink absorbs a portion of the visible light spectrum. If all the visible light has been absorbed by the components in an ink mixture or in any other object, no light bounces off the object and hits our eyes. So we see no color and we describe the object as being black.

Brand of marker	What did you observe?

Celebrating Chemistry

Celebrating Chemistry is a publication of the ACS Department of Volunteer Support in conjunction with the Committee on Community Activities (CCA). The Department of Volunteer Support is part of the ACS Division of Membership and Scientific Advancement. The National Chemistry Week (NCW) edition of *Celebrating Chemistry* is published annually and is available free of charge through your local NCW Coordinator. NCW is a combined effort among CCA and several ACS Technical Divisions. Please visit www.acs.org/ncw to learn more about NCW.

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 158,000 members. ACS members live in the United States and different countries around the world. Members of the ACS share ideas with each other and learn about important discoveries in chemistry during scientific meetings held around the United States several times a year, through the use of the ACS website, and through the many peer-reviewed scientific 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 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 at **outreach@acs.org**.

ACS Chemistry for Life®

Words to Know

Anthocyanin: a class of water-soluble pigments that give flowers the colors red, purple or blue depending on the pH of the soil they're growing in (pH tells how acidic or basic something is.)

Capillary action: the ability of a liquid to flow in narrow spaces without the help of (and even against) external forces like gravity. Capillary action is how water flows up into plant roots, and how paper towels "soak up" spills.

Chlorophyll: the green pigment in plants that absorbs energy from sunlight to convert carbon dioxide and water into oxygen and sugar. This process enables plants to make their own food.

Colorant: a dye, pigment, or other substance that gives color to matter.

Iridescent: showing bright "rainbow" colors that seem to change when seen from different angles. Examples include peacock feathers, soap bubbles, and butterfly wings.

Magnesium: a metallic element (also known by the symbol Mg) that gives off a bright white light when burned, and is used in fireworks, sparklers, and flares.

Pigment: Tiny particles that change the color of reflected light (the color you see) by selectively-absorbing colored light of other wavelengths (the color you don't see).

Propellant: pressurized gas that causes something to move forward.

Visible Spectrum: the range of light that is normally visible to the human eye. This range of light has wavelengths from 380 to 760 nanometers.

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