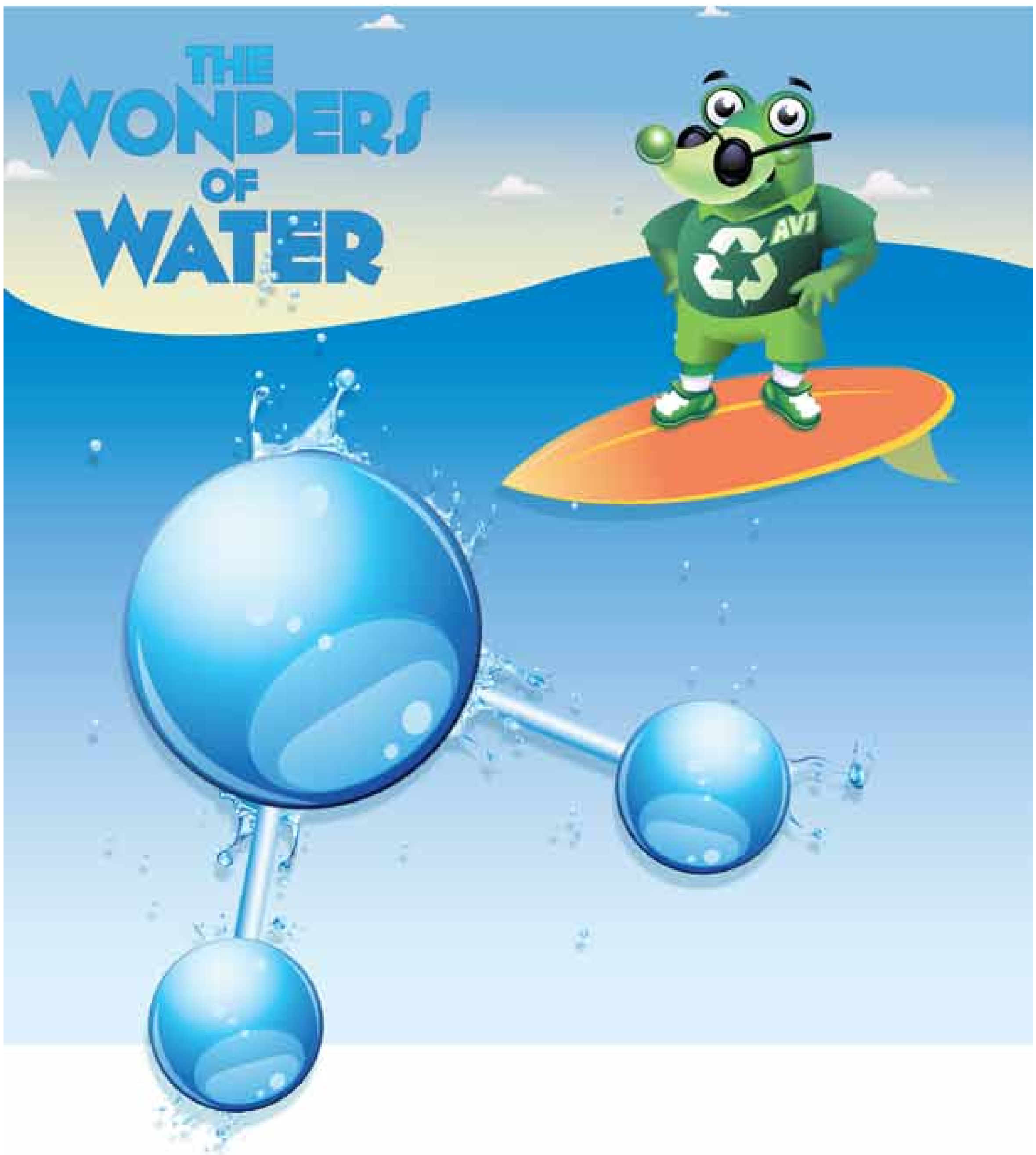
ACS
Chemistry for Life®

Celebrating Chemistry

CHEMISTS CELEBRATE EARTH DAY

AMERICAN CHEMICAL SOCIETY



The Wonders of Water

By Analice Sowell

Did you know that water covers almost three-quarters of the earth's surface? Your body is almost 77% water, while an adult's body is composed of 50-60% water. Water plays an important role in our lives. A healthy person can survive weeks without food, but only days without water.

In addition to drinking water, we use it in many of our other daily activities. In this edition of *Celebrating Chemistry*, we will look at some properties of water that make it unique. Have you ever wondered why water takes the shape of a drop or how some insects are able to walk on top of water? Or, how some insects are able to walk on top of water? How does water stick to the leaves of plants to help keep them hydrated? To answer these questions, you need to know a little about some of the really exciting properties of water known as ***cohesion***, ***surface tension***, and ***adhesion***.

We also use water to clean ourselves, our clothes, and many other things. But why do we have to use soap along with the water? ***Surfactants*** are a really interesting area of chemistry that looks at how to use detergents to remove dirt from practically everything!

In the United States, most of us can be sure that the water coming into our homes through the faucet is clean. In many areas of the country, water is cleaned naturally through layers in the ground in an ***aquifer***. The water in aquifers gets cleaned by percolating down through the rocks and sand.

But our supply of water can be affected by other things we do in our lives. For example, we use a lot of energy to heat our homes, provide electricity, move us from place to place, and run our factories. Much of this energy is provided by oil. There have been accidents and large amounts of oil have spilled into our oceans and caused environmental issues. We will also look at a model of an oil spill and discover the best way to make the water clean again using what we know about its unique properties.

Take a moment and see all "The Wonders of Water" in this issue. The more you know about water and how it helps us, the more you can learn how to help it stay clean and sustainable for years to come!

Analice Sowell *is Chair of Chemists Celebrate Earth Day, a program of American Chemical Society.*

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!

Soft Water and Suds

In many parts of the country, the water that people use to wash their clothes contains minerals that affect the cleaning properties of detergents and soap. That's why water softeners are popular in these areas. Water softeners remove minerals and help the detergents produce suds the way they should. In this activity, you will look at the sudsing power of detergent in hard water and in soft water.

SAFETY

- Safety goggles required
- Do not eat or drink any of the materials used in this activity
- Thoroughly wash hands after this activity
- Use a scoop or spoon to dispense dry chemicals

Materials

- 2 cups of distilled water
- 1 teaspoon Epsom salts
- 2 empty, clean 2-L plastic soft-drink containers with screw caps
- Several drops of liquid dishwashing detergent (but not the kind made for automatic dishwashers!)

Procedures

1. Pour 1 cup of distilled water into both of the empty soft-drink bottles. Add 1 teaspoon of Epsom salts to one of the bottles. Swirl the bottle until the Epsom salts dissolve.
2. Add 5 to 6 drops of liquid dish detergent to each bottle.
3. Seal the bottles with their caps, then shake both bottles.
4. Record your observations in the chart provided!

WHAT DID YOU SEE?		
	Describe what the suds look like.	Draw a picture of what the suds look like.
Distilled water (soft water)		
Distilled water and Epsom salts (hard water)		

Where's the Chemistry?

Calcium and magnesium are in the minerals that make water "hard." In this activity, you made hard water by adding Epsom salts, which contains magnesium. Minerals interfere with the cleaning action of soap because they form a scum that does not dissolve in water, and can even make what is being washed look dingy. Sometimes you can overcome this by adding more soap or detergent. The "ring" that is frequently left on the sides of the bathtub is also formed in this way.

Adapted from Bassam Shakhashiri's activity, "Soft Water and Suds," in CHEMICAL DEMONSTRATIONS: A Handbook for Teachers of Chemistry, Volume 3.

Why Water and Oil Don't Get Along

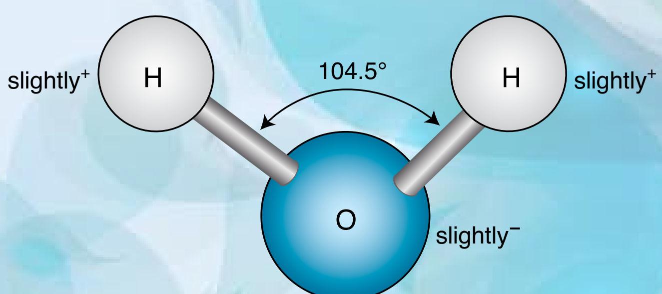
By Roberta Baxter

Water and oil don't mix easily because of the way atoms are arranged in their molecules. All matter is made up of tiny particles known as atoms. The center of the atom is the nucleus and it has a positive charge. Along the outer edges of the atom are the electrons, which have negative charges. The electrons can form bonds that tie atoms together into molecules.

For example, a water molecule has three atoms — two hydrogens and one oxygen, written as H_2O. Oil is made up of atoms of carbon and hydrogen, also bound together by electrons. A molecule of oil can have many atoms of carbon and hydrogen, all linked together.

However, water and oil molecules are very different from each other. One way they are different is in polarity. ***Polar molecules*** are special because they have areas of slightly positive and negative charges — and water is a great example. Polar molecules are also usually ***hydrophilic***, a term that comes from two words that literally mean "water loving."

If you look at a drawing of a water molecule, it is not straight, it is bent. This shape and the type of bonds holding a water molecule together gives the hydrogen end of the molecule a slightly positive charge and the oxygen end a slightly negative charge.



Any molecule that is polar (like water) will be attracted to water and able to mix with it. As the saying goes, "opposites attract." The positive charge (hydrogen side) of one molecule is attracted to the negative charge (oxygen part) of another molecule.

The carbons in oil are "generous atoms" that share electrons equally with the hydrogen atoms around them. The whole molecule has a neutral charge because the electrons are all equally spaced around it. This means that oil is a ***nonpolar substance***.

Oil and most nonpolar molecules are ***hydrophobic***, which means that they don't mix with water or dissolve in it easily. Because of their bulky size and shape, oil molecules prefer to be close to other oil molecules, arranging themselves in an ordered fashion, while still interfacing with water.

Oil is nonpolar and hydrophobic. Water is polar and hydrophilic. So oil and water do not mix!

Polar Fact:

When we say that water is a polar substance, we're not saying that it's cold, or that it came from the North or South Pole. Instead, we're just saying that it has areas that are slightly positive and slightly negative.

The Adventures of Meg A. Mole, Future Chemist

Gary Emmert,
Associate Professor of Chemistry

For Earth Day 2014, I did a little research on drinking water in different cities throughout the US. Unlike many other places around the world, the water in Memphis, TN is clear, fresh-tasting, and has virtually no odor! After reading about that, I decided to visit the hometown of Elvis Presley and Dr. Gary Emmert! Dr. Emmert is an Associate Professor of Chemistry at the University of Memphis.

Dr. Emmert explained how his research helps the drinking water in the city of Memphis. “We develop new electronic devices that help improve the quality of drinking water. These devices tell the water treatment plant operators that the water they are producing is safe to drink by measuring the amounts of certain chemicals used to treat the water and turn it from ‘natural water’ to ‘drinking water.’ For example, we work with town and city water treatment plants to help them understand how to add just the right amount of a water disinfectant, chlorine, to kill harmful microorganisms (that means germs!) but not to add too much and produce harmful chemicals that may make you sick.” He also told me about another cool project, where his team “worked with engineers at NASA to develop devices for monitoring the amounts of disinfectants in the water that astronauts drink on the International Space Station.” Their chemistry is out of this world!

While visiting Dr. Emmert’s laboratory, I met a lot of graduate students. They wore lab coats and safety glasses, and some of them even had on gloves, heavy aprons, and clear plastic facemasks. Dr. Emmert explained it was important for them to wear protective equipment “when they are doing certain dangerous tasks.” In the laboratory, they also use a lot of computers, which serve as the ‘brains’ of the instruments they build, allowing them to record data and make sure everything runs like it should!

Dr. Emmert was very interested in chemistry growing up. He told me about how he “had a chemistry set and he really enjoyed experiments where he could create a color or cause a color to disappear. Even today,” he added, “I use some of that same sort of chemistry in the devices that I design.” Also, he told me about one of his “earliest heroes, Mr. Spock on ‘Star Trek’ … the science officer!” Dr. Emmert loved how Mr. Spock “could always figure things out to get his team out of trouble, often using a handheld electronic device called a ‘tricorder.’ The tricorder was a make-believe device that could detect and measure almost anything, and Mr. Spock used it all the time.” As Dr. Emmert got older, he said, “I became an analytical chemist because I wanted to build devices like the tricorder that could help people figure out things that they needed to know.”

Dr. Emmert explained how his work really helps many people. “Having a safe supply of drinking water is important to everyone, on earth or in space. A little over a hundred years ago, one of the most common ways people got sick was by contacting germs through drinking water. Today, the number of people in the developed world who get sick from drinking water is very low. The devices that we have built help make this possible. But the problem of not having a safe supply of drinking water is still a concern in many other parts of the world. So we need to make our devices more portable, cheaper, and easier to operate so we can improve water quality worldwide — and even beyond, as we move out to other planets.”

Personal Profile

FAVORITE COLOR?
Deep blue — like water on a picture of Earth shot from space!

INTERESTING PROJECT YOU WERE A PART OF?
One of my inventions is now a commercially available device used by water treatment plants to analyze water samples. In one location, our device has been operating continuously for about five months and has analyzed over 4200 water samples. Can you imagine working for five months straight without a break?

ACCOMPLISHMENT YOU’RE PROUD OF?
Some of the devices that I have designed have been awarded United States patents, and have been used by water treatment plants to improve water quality.

ABOUT YOUR FAMILY?
I met my wife, Wei, in graduate school. We have two young sons — Noah, who is almost 10 years old, and Ike, who just turned 5. Both of my sons like science and technology as well.

What's Going on Underground?

Aquifers!

By Robert A. Yokley, Ph.D.

An ***aquifer*** is a layer of rock underground that water can move through. The study of aquifers is called ***hydrogeology***. Aquifers are a very important source of fresh water for people who use springs and wells for their water supply. Aquifers fill with water from rain or melted snow that drains into the ground.

The rocks in the aquifer have openings, called ***pores***, that allow the water to flow through. The bigger the openings, the more water can flow through the rock. The amount of water that flows through the rock also depends on the type of rock and the size of the rock pieces. Water can flow more easily through large rocks because the channels between the rocks will be larger. Water will flow less easily through small rocks (like sand) because the channels and pores will be smaller.

The ***water table*** is at the top of the aquifer. This is the level where we find our groundwater. If you dig a hole in the ground that reaches the water table, the hole will fill partially with water. All of the openings in the rocks below the water table are completely filled with water. This is called ***saturation***.

The amount of groundwater that flows each day depends on the type of rock present. Hard, solid rock (with few pores), like shale, might only allow a few centimeters of water to flow through it in 100 years. Softer rock (with more pores) could let several meters of water pass through it in a day. The zone above the water table has some water in it, but it is not completely filled with water. This is called ***unsaturation***. The roots of plants live in this area of the ground.

Water can be naturally purified when impurities are released to the air as water trickles over rocks in a stream (***aeration***). Other impurities are removed when water

freezes (formation of icebergs) or are left behind when water evaporates and then condenses again to a liquid (rainfall). Water can also be naturally purified as it seeps ***(percolates)*** through the rock and soil. For example, solid particles can be filtered when the water passes through rocks with small pores.

Surface Tension, Cohesion, Adhesion: Let's Stick Together!

By Roberta Baxter

You can float a pin or a paper clip on water because the top layer of water acts like a "skin." The skin forms because of the behavior of the molecules of water. Remember: water molecules have a slightly positive part and a slightly negative part. The slightly positive parts of the water molecule attract the slightly negative parts of neighboring water molecules.

The attraction between molecules of water is called ***cohesion***. Cohesion makes water form drops. If you put water on a piece of wax paper, large drops of water will ball up. The oil of the wax paper slightly attracts the water molecules. But the forces sticking the water molecules together are stronger, so they stick together and form drops.

You can try to spread the water out, but it will keep rolling up into drops. Try this yourself by dropping some water on a piece of wax paper. Using a toothpick, play with the drops and see what happens.

Inside a glass of water, cohesion is pulling the molecules together. However, at the surface of the water, the molecules don't have other water molecules to grab on one side. The water molecules at the surface are not attracted to the air above them, only to the other water molecules below them. The cohesion causes the molecules to act like a stretchy skin-like covering over the surface of the water. This is called ***surface tension***.

We know water molecules stick to each other, but they can also stick to other things like paper or glass! The tendency for different things to stick to each other is called ***adhesion***. How well different things stick to each other depends on the forces between their molecules. Water molecules are attracted to the glass more strongly than to other water molecules. Because of this, the water molecules are held against the glass in a thin film instead of in drops, as in the wax paper example.

Surface tension, cohesion, and adhesion are important properties of water that help all life on earth to survive.

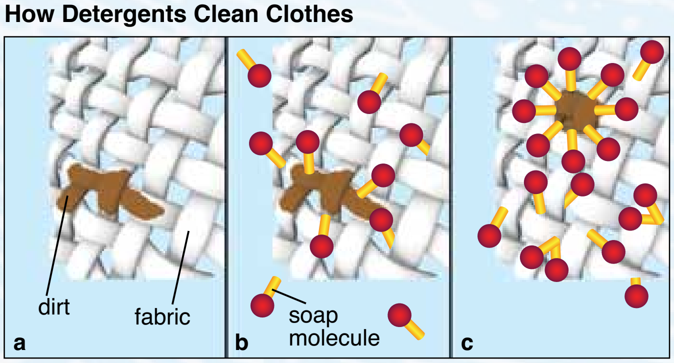
The Science of Getting Things Clean

By Roberta Baxter

Substances called ***surfactants*** are needed for cleaning oil and dirt from clothes, dishes, and you! Soaps and detergents are types of surfactants, and each of their molecules has a section that is hydrophilic (water loving), so they're attracted to polar water molecules. Another part of the surfactant molecule is hydrophobic (water hating), and is attracted to nonpolar molecules, such as oils.

Adding a detergent to water makes the cohesive forces in water decrease. Water molecules touch several other water molecules at a time, leading to large drops. Detergent molecules get in between the water molecules. The hydrophilic part of the detergent stays attracted to water. When clothes are being washed in soap and water, the hydrophobic part pulls oil drops out of the cloth. The detergent molecules keep the water from forming large drops and turn it into smaller drops that carry away the oil. The detergent helps the oil and water mix … even though they usually would not.

How Detergents Clean Clothes



Shampoos and body wash also contain chemicals that are part hydrophilic and part hydrophobic. The shampoo or body wash has ingredients that allow oils and waters to mix by lowering the cohesion of the water molecules. This allows them to suspend oil from hair or skin into the washing water so it is removed.

If the water that is used for washing contains minerals, such as calcium and magnesium, it is called ***hard water.*** If soap lathers up easily, you probably have ***soft water***. But if the soap hardly lathers at all and forms a grayish scum, it is hard water, meaning it has high levels of calcium and magnesium ions dissolved in it. You can also see the evidence of hard water in a tea kettle. The hard water will leave a solid white crust at the bottom of the kettle after the water has boiled.

The calcium and magnesium are dissolved in the water because these substances are in the rock where the water came from. When the detergent molecules react with the calcium or magnesium, the products are insoluble (don't dissolve), so the gray scum appears.

Hard water is not dangerous to drink, but it makes detergents not work as well as they would in soft water. Usually, you must add more detergent to your laundry or use more body wash if the water is hard. Some people add water softeners to their water lines to remove the calcium and magnesium to make it softer and allow detergents to work better in their dishwashers and washing machines.

Word Search

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

F O S I T H R C I L I H P O R D Y H H
Q I R R N A R P N H S S I D H R A S A
C O E E E D R W E M P L D O C T C L Q
O E R T G G E R A N A O I L C F E A U
H E H A R D W A T E R Y L E O H C R I
E H O W E H O I N R S A R A L A R E F
S A E T T N A T C A F R U S R T T N E
I N A F E Y H Y D R O P H O B I C I R
O A P O D O R D I S P E R S A N T M E
N O I S E H D A H A A S E A R D R Y P

ADHESION	DETERGENT	HYDROPHILIC	POLARITY
AQUIFER	DISPERSANT	HYDROPHOBIC	SOFT WATER
COHESION	HARD WATER	MINERALS	SURFACTANT

What Happens in an Oil Spill

By Roberta Baxter

In March 1989, the oil tanker *Exxon Valdez* spilled about 11 million gallons of oil onto Alaska's shoreline. Over more than 87 days in 2010, more than 200 million gallons of oil pumped into the Gulf of Mexico during the Deepwater Horizon (or BP) oil spill. These two huge oil spills damaged birds, marine life, and shorelines.

When oil is dumped into something even as large as the ocean, it doesn't mix into the water. Instead, it floats on the surface of the water. Then, when the tide washes up on the shore, oil travels with it and coats the sand and rocks. These areas become coated with black, gunky residue that is not washed off by additional waves.

There are many ways to clean up an oil spill. A "boom" acts like a floating fence, and can be placed around a spill to stop it from spreading. Oil companies can also use skimmer boats that collect and absorb the oil off of the surface of the water with a machine.

Another solution is to use a ***dispersant***, a special type of surfactant. The dispersant is sprayed onto the surface of the oil spill. This mixture of chemicals reduces the surface tension of the water and helps the oil break up into small drops suspended in the water. Once the oil is in smaller drops instead of a film on the water surface, it cannot coat the shoreline or birds that land on the water.

Marine life that is coated in oil can die, because the oil destroys the protection of their fur or feathers. For example,

bird feathers have tiny barbs that stick together like Velcro, keeping the bird dry and warm. Oil sticks the feathers together, and then water and air can get in. The bird can die from cold. The oil is also toxic to birds if they swallow it.

After oil spills, volunteers and rescue people carefully wash birds with detergent to remove the oil. The detergent molecule has one part that holds onto oil and another part that is attracted to the water. It can break up the oil blobs and let them wash away in the rinse water. After the bird is clean, it is carefully dried while it preens its feathers back into their waterproof positions. If the bird survives the trauma of being coated with oil and then cleaned by humans, it is released into the wild.

Sea animals, such as sea lions and seals, also are impacted by oil. Volunteers clean them with detergents and once they are healthy, they are let go.

Oil Spill!

By Analice Sowell and Christine Jaworek-Lopes

In this issue of *Celebrating Chemistry*, you learned about the properties of water, oil, and oil spills. It's time to act like environmental chemists and engineers and use your knowledge to try and clean up a "mini-oil spill" you create!

SAFETY

- Safety goggles required
- Protective clothing suggested
- Do not eat or drink any of the materials used in this activity
- Thoroughly wash hands after this activity

Materials

- 1 aluminum pie pan
- 2 bird feathers
- Water
- 1 tbsp. vegetable oil
- Blue food coloring
- 1 small cup for collecting skimmed oil/water
- 1 plastic spoon (for skimming oil from the pie pan)
- Various types of products that might absorb oil, such as cotton balls, paper towels, oil-absorbing facial tissues, and discarded fabrics
- 1-2 drops of "grease fighting" dishwashing detergent

Procedures

1. Fill a pie plate half-full of water. Add a few drops of blue food coloring and stir.
2. Add about 1 tablespoon of vegetable oil to the water and stir. Describe what happens to the oil.
3. Place a feather in the oily water. After 30 seconds, remove the feather and write down how the oil has affected the feather. Based on what you observe, what impact do you think an oil spill might have on birds?
4. Use the skimmer (spoon) to try to remove the oil. Put any recovered oil into the small cup. Try to take only the oil off the surface and not remove water. Rate your success at removing the oil.
5. Test the products you think will absorb the remaining oil and see which one removes the most oil. Record your results in table 1.
6. Add 1-2 drops of dishwashing detergent to the water/oil mixture. Stir it with the spoon. Describe what happens to the oil.
7. Take another feather and dip it into the pan. Compare this feather to the one that was dipped in the water/oil mixture at the start of the experiment. Describe or draw what you see in table 2.

Table 1

Oil-Absorbing Product	How Well Did It Work?					
	Did not absorb					Absorbs the best
	0	1	2	3	4	5
	0	1	2	3	4	5
	0	1	2	3	4	5
	0	1	2	3	4	5
	0	1	2	3	4	5
	0	1	2	3	4	5

Table 2

Clean Feather	Feather in Mixture	Feather in Water/Oil/ Dishwashing Detergent Mixture

How Does It Work? Where's the Chemistry?

Oil and water don't mix because water is a polar substance and oil is a nonpolar substance. Oil will float to the surface of the water since it is less dense than water. Skimmers are machines used to remove the oil that is sitting on the surface of the water. In a real oil spill, chemists and engineers not only have to clean the water, but they also have to clean any animals that may have gotten oil on their fur or feathers. Surfactants, or soaps, are used to help break apart the oil into little droplets within the water. Then, microbes can break down the oil to clean the water in a way that scientists and engineers doing the clean-up cannot.

Adapted from the "Oil Spill" lesson at www.teachengineering.org.

Clean-up Tips!

- The water/oil mixture can be washed down the drain
- Products used to absorb the oil should be thrown in the trash

Words to Know

Adhesion – the force that holds together molecules that are different

Aquifer – an underground layer of rock, gravel, or sand that water can move through

Cohesion – the force that holds similar molecules together; this force allows water molecules to form drops

Detergent – a substance used to clean by helping oil and water mix

Dispersant – a substance that allows a sheet of spilled oil to break apart and form smaller drops

Hard water – water that contains dissolved minerals such as calcium or magnesium

Hydrophilic – "water loving," such as a molecule that attracts water and is readily absorbed or dissolved in water

Hydrophobic – "water hating," such as a molecule that repels water or does not dissolve in water

Minerals – naturally-occurring substances in the earth's surface that have unique crystal structures (or arrangements of atoms), such as elements, ores, or salts

Polarity – the separation of slightly positive and negative charges in a bond or molecule (water molecules, for example, have both positive and negative areas)

Soft water – water that contains little or no dissolved minerals

Surfactant – a chemical, such as a detergent, that lowers the attraction among molecules

Celebrating Chemistry

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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. 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**.

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The activities described in this publication are intended for elementary school children under the direct supervision of adults. The American Chemical Society cannot be responsible for any accidents or injuries that may result from conducting the activities without proper supervision, from not specifically following directions, or from ignoring the cautions contained in the text.