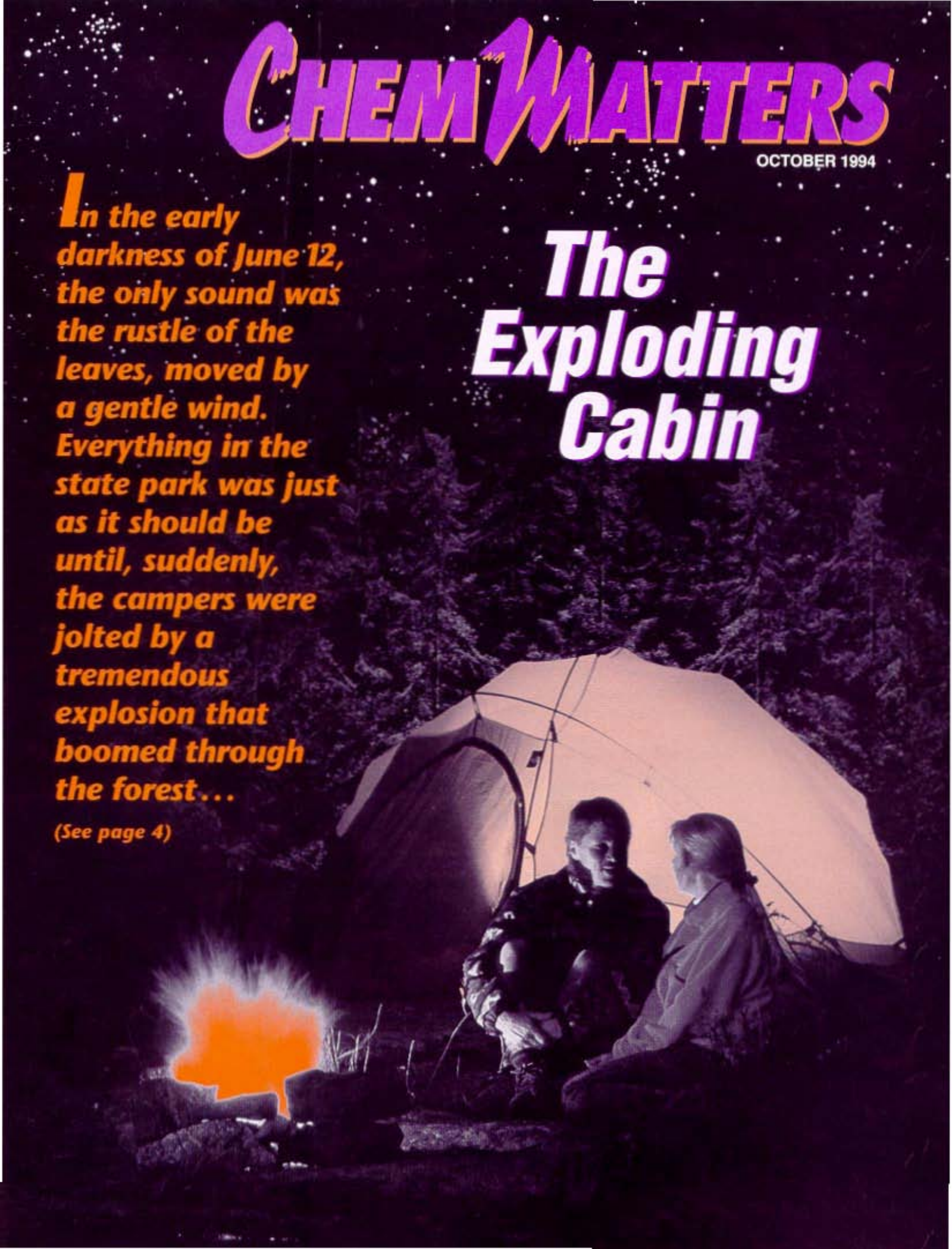
CHEM MATTERS
OCTOBER 1994

The Exploding Cabin

In the early darkness of June 12, the only sound was the rustle of the leaves, moved by a gentle wind. Everything in the state park was just as it should be until, suddenly, the campers were jolted by a tremendous explosion that boomed through the forest...

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MYSTERY MATTERS

THE E*X*P*L*O

by Harvey Black

In the early darkness of June 12, 1993, all was quiet in the woodlands of Tahquamenon Falls State Park, Michigan. Campers were sound asleep in their tents. The only sound was the rustle of the leaves, moved by a gentle wind.

Everything was just as it should be until, suddenly, the campers were jolted by a tremendous explosion that boomed through the forest.

The old ranger station had just blown up. Campers a mile and a half away reported hearing the noise. By the time daylight rolled around, the results of the explosion were clear, but the cause was a mystery.

"There was considerable damage to the building," said Wayne Suida, the park manager who surveyed the shambles that the 16- by 40-foot wooden building had been reduced to. "All of the walls were damaged to some extent," he said. The northeast wall of the building was blown out quite badly from the bottom up. The top of that wall came to rest 20 feet from the building. Concrete blocks from the building were strewn about the area. The roof at the north end of the building was damaged. "The roof at that end of the building was actually sagging down about 4 or 5 feet from its normal level," Suida said.

"It was a very powerful explosion. Debris was scattered 150 feet away from the building," said Sergeant Wally Helmila of the Michigan State Police Fire Marshal's Office, who searched for the cause of the blast. Significantly, an enclosed porch that served as entrance to the basement was gone. "It was totally decimated," said Helmila.

What or who caused such a destructive blast? Could someone have deliberately destroyed the building? A new ranger station had recently been built nearby and the old one was now owned by the construction company that built the new station. However, the company had canceled its insurance policy on the old building two weeks prior to the explosion. Foul play seemed unlikely because



PHOTO: TAHQUAMENON FALLS STATE PARK

*D*I*N*G CABIN



PHOTO: TOM MCHUGH, PHOTO RESEARCHERS

Left: **After the blast. Fortunately this ranger station at Tahquamenon Falls State Park was not in use when it exploded. Because a new station had been constructed, this building was closed and the propane gas was turned off at the supply tank. The blast caused no injuries, but investigators found its cause elusive.**
Above: **Bats became the prime suspects in the explosion investigation when it was discovered that a large colony had been roosting in the attic of the ranger station.**

no one would profit from the building's destruction.

What about a gas leak? Not very likely. The propane-fueled furnace had been removed from the building about a month previously, when the new station was opened. What's more, the gas had been shut off at the tank, some 20 feet from the building.

But the electricity was still working. It was needed to run a sump pump because water from spring rains sometimes flooded the basement.

In the basement Helmila found a "tremendous amount of damage" according to his report. The beams supporting the floor above were shattered and scorched. It looked like the sump pump had triggered the explosion, but what was the combustible material that exploded?

As he continued his probing of the remains of the building, searching for a cause, something caught Helmila's eye. It was a black substance on the ground under the remains of the basement entrance porch. It looked like bat droppings to Helmila.

Bats had been roosting in the attic for three years or more, and bat dung had accumulated in thick layers. Suida said that the bats had entered through a gap in the cedar shingles on one side of the building.

Was it possible that methane gas, which can be given off by decaying dung, was responsible for the explosion? Methane is an odorless, colorless, but potentially explosive gas. In fact, it is the main component of "natural gas" used in Bunsen burners as well as many kitchen stoves and home furnaces.

Helmila got in touch with a zoology professor at Michigan State University, and was told this was possible. Accordingly, the State Police report explained the explosion this way: The decaying bat dung emitted methane; being heavier than air, the methane sank to the basement; water entered the basement and drained into the sump, which

caused the sump pump to switch on; the spark from the electric pump ignited the methane/air mixture; the building blew up.

When reporters got hold of this possible explanation, it became hot news. The local newspaper's headline was *HOLY BLAM, BATMAN! Bat dung brews methane; park building explodes*. Radio commentator Paul Harvey repeated the story on his national program. And humorist Dave Barry wrote about it in his syndicated newspaper column. "There was a great deal of publicity," says Suida. "We had calls from radio talk shows. I had telephone calls from as far away as England."

But at least one person didn't think it was funny. Biologist Merlin Tuttle, a bat expert, practically exploded himself when he heard this explanation for the destruction of the building.

"Preposterous!" is the way Tuttle describes that explanation. "There's never been any case known in all the history of batdom of anything anywhere exploding from bat guano. In fact there's no evidence that bat guano produces methane or any other combustible gas." Tuttle is head of Bat Conservation International, an Austin, Texas-based scientific organization dedicated to informing the public about the ecological value of bats. "If bat guano produced methane, cave explorers would have been blowing themselves to smithereens for years. It doesn't happen," he explains.

Tuttle's contention is borne out by bacteriologist Jorge Escalante of the University of Wisconsin–Madison. Escalante, who has specialized in studying the microbes that produce methane, says that these microbes can be found in the guts of bats and other mammals. But, he says, "the dung is very porous, and once it dries out, I don't think there would be a sufficient amount of methane for an explosion."

The microbes that make methane are anaerobic; they can't live in the presence of oxygen. So they would simply die when air entered the porous dung.

Another strike against the bat dung hypothesis is that methane molecules, with one carbon and four hydrogen atoms, are far *lighter* than air, not heavier (see Table 1). Consequently the gas would not have sunk to the basement, as proposed by the Fire Marshal's report.

If not methane from bat dung, what was responsible for the explosion? The state police began to reexamine the evidence and came to another conclusion. In the end, methane was blamed for the explosion, but it did not come from bat waste.

The toilets in the old ranger station were connected to an underground septic tank. Normally, U-shaped traps in the pipes are filled with water, and the water prevents gases from flowing backward into the building (Figure 1). Because the building had been empty for some time, the water evaporated, allowing the methane generated in the septic tank to back up into the building.

Then, as in the scenario that erroneously blamed the bats, a spark from the sump pump ignited the methane.

Just how does methane form? As Escalante explained, many microorganisms break down the complex organic molecules present in the waste of mammals. "This first stage will break down the polymers into a number of fatty acids, including acetate, formate, CO_2, and hydrogen," he says. "These are prime substrates for methanogens." The methanogens metabolize these components, chiefly hydrogen and carbon dioxide, and produce methane, CH_4. (See the article "Wastewater" in *Chem Matters*, April 1992) Methanogens are highly specialized microbes that eat, "at the end of the food chain," in what Escalante calls the "phenomenally complex environment" of sewage. They can survive only in the absence of oxygen and live in city sewage systems, simple septic systems like the one at Tahquamenon Falls State Park, and our intestines.

So, after many false leads, the puzzle of the exploding ranger station was resolved. The explosion was caused by methane from mammal waste but the waste came, not from the insect-eaters that roosted upside down in the attic, but from their accusers.

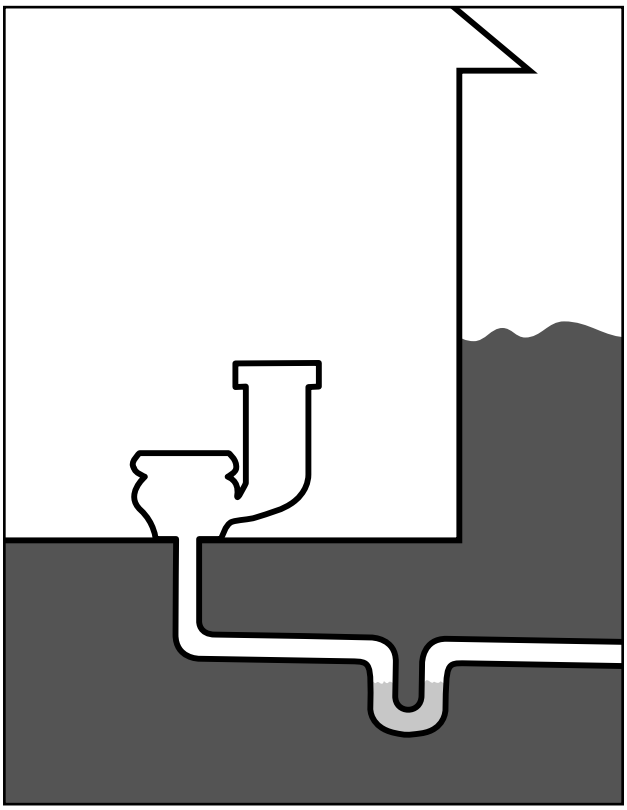


Figure 1. When a toilet is flushed most of the water (and the waste) flows into the sewer or septic tank. Some of the water is retained in the U-shaped trap where it prevents gases from flowing back into the building.

Table 1. Molecular weight of natural gas and air. The density of a gas is determined by the molecular weight of its molecules. Natural gas has a slight tendency to float upward because its molecular weight, 17 amu, is less than the average molecular weight of air, 28.95 amu.

Natural gas composition			Air composition		
Methane, CH_4	16 amu	94.5%	Nitrogen, N_2	28 amu	78.08%
Ethane, C_2H_6	30 amu	4.1%	Oxygen, O_2	32 amu	20.95%
Propane, C_3H_8	44 amu	1.3%	Argon, Ar	40 amu	0.93%
			Carbon dioxide, CO_2	44 amu	0.03%
Average	**17 amu**		**Average**	**28.95 amu**	

Harvey Black *is a science writer in Madison, Wisconsin.*

PET Recycling

It's not easy getting new shirts from old bottles

by Christine Plummer



PHOTO: MIKE CIESIELSKI

PET soda bottles can be recycled into many useful items—from new soda bottles to carpet to clothes. Five 2-liter bottles can be transformed into one T-shirt or the fiberfill insulation for one ski jacket. A square yard of polyester carpet requires recycling 36 bottles. In 1993, Americans recycled 30% of the PET containers they purchased.

Like casual clothes? How about slipping into some old soda bottles? This is not as crazy as it sounds because the plastics industry is now recycling soda bottles into polyester fibers that are woven into T-shirts, parkas, and other garments.

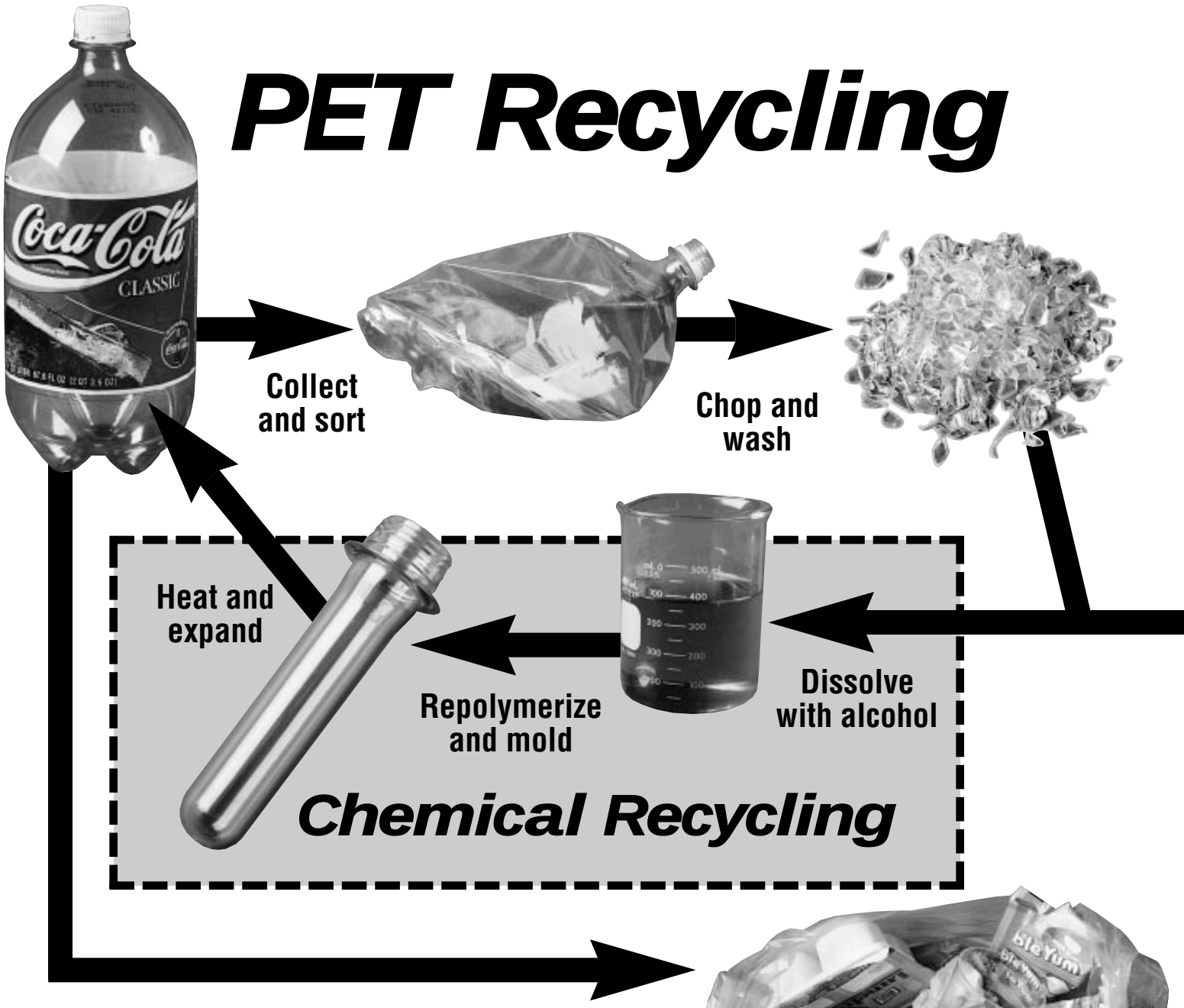
When you buy a two-liter bottle of Pepsi or Coke, it comes in a plastic bottle made of polyethylene terephthalate, PET for short. PET has all the right properties for transporting soda: It is strong but unbreakable, lightweight, transparent, and gas-tight so the CO_2 fizz doesn't escape. And it is a recycling success story.

PET is a thermoplastic—a material that can be repeatedly melted and reshaped. When heated, the molten PET can be pressed into molds to make bottles or furniture, or it can be spun—squeezed through tiny holes to form fibers that can be woven into fabric for use in carpets, clothing, or quilts. When the product reaches the end of its useful life, it can be recycled by either a physical process or a chemical process.

When a soda bottle is physically recycled, it is simply chopped into pieces, washed, and then melted so it can be molded or spun again. However, the fibers are of lower quality than those made from "virgin" PET. This is why soda bottles are usually reborn as carpet, tennis ball felt, automobile parts, or boat hulls. What's more, because the Food and Drug Administration is concerned that some microbes might survive the melting process, the U.S. government agency does not permit plastic from old food containers to be simply melted and reformed into new food containers. Food containers that are made from recycled materials are produced by a more expensive chemical recycling process.

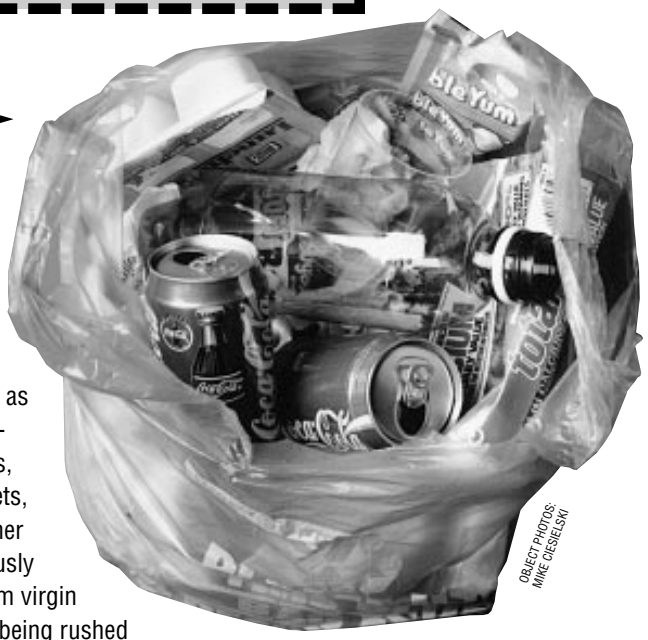
PET is a polymer that contains large molecules made by linking two simple compounds. It is possible to reverse the process—depolymerize the PET—and then treat the simple compounds to remove all impurities. (See box Making and Unmaking of PET.) This chemical recycling process is expensive, but it results in pure PET that can be used to make fine fibers or food-grade containers.

One of the first companies to recycle PET was Wellman, Incorporated, which began spinning recycled fibers in 1972. "When we first wove a fabric from recycled green bottles, it was at 6 denier and a really ugly lime green. We took it to clothing manu-



facturers, laid it out, and needless to say, they were not enthused—back to the lab," says Don Cartwright, research and development manager at Wellman. "The secret to consumer acceptance of fabric made from polyester is in the ability to dye the product and to get the recycled material clean enough to produce fiber down to small deniers [a measure of yarn size equal to the mass in grams of 9000 meters of the yarn] so that it feels good, what we call 'hand' in textiles. Without depolymerizing, a certain amount of leftovers from labels, glue, etc., adhere to the polyester. This affects the final fiber. We were able to reduce the fiber size from 6 to 3.5 denier. Fiberfill (insulation for parkas and sleeping bags) and carpet, the most common uses for recycled PET, are generally 15–16 denier. Now we're working on an even finer fiber and have developed a heather-look textile." Cartwright credits Dave Lambert and Jim Ciccone with figuring out how to dye the recycled fiber.

Their efforts resulted in major media attention last year when Patagonia, a well-known manufacturer of outdoor wear, chose Wellman's recycled fibers for use in ski jackets. Now products such as thermal underwear, sweaters, jackets, blankets, shoes, and other goods, previously made only from virgin polyester, are being rushed to market to meet consumers' demand for products made from recycled materials.

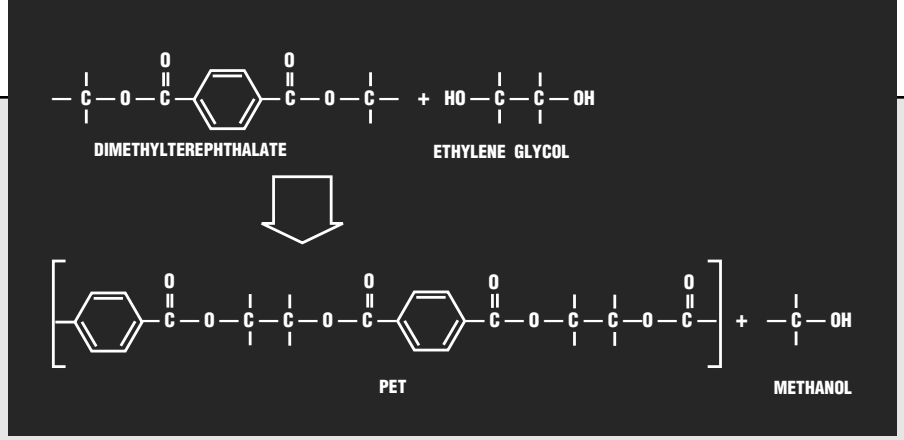


OBJECT PHOTOS: MIKE OBSIELSKI

Trash

Although textiles presently consume most of the recycled bottles, companies are experimenting with other creative uses for the product.

Making and Unmaking of PET



Polyethylene terephthalate (PET) can be produced by reacting ethylene glycol with either terephthalic acid or dimethylterephthalate (as shown here).

PET is a long chain-like molecule. In a typical PET molecule, the portion shown in brackets above is repeated 40 to 50 times. The solid PET is formed into chips or pellets that are shipped to other companies, where they are melted and formed into the final product.

After the plastic product is used, it may be physically recycled (by simple melting) or chemically recycled. In chemical recycling, the plastic is chopped into flakes, methanol is added, and the mixture is heated under pressure to reverse the above reaction and break the PET down into the original dimethylterephthalate and ethylene glycol. These compounds are purified, mixed with virgin dimethylterephthalate and ethylene glycol, then repolymerized. The recycled material is indistinguishable from the original virgin PET.

Coca-Cola is now using chemical recycling to make some of its Coke bottles.

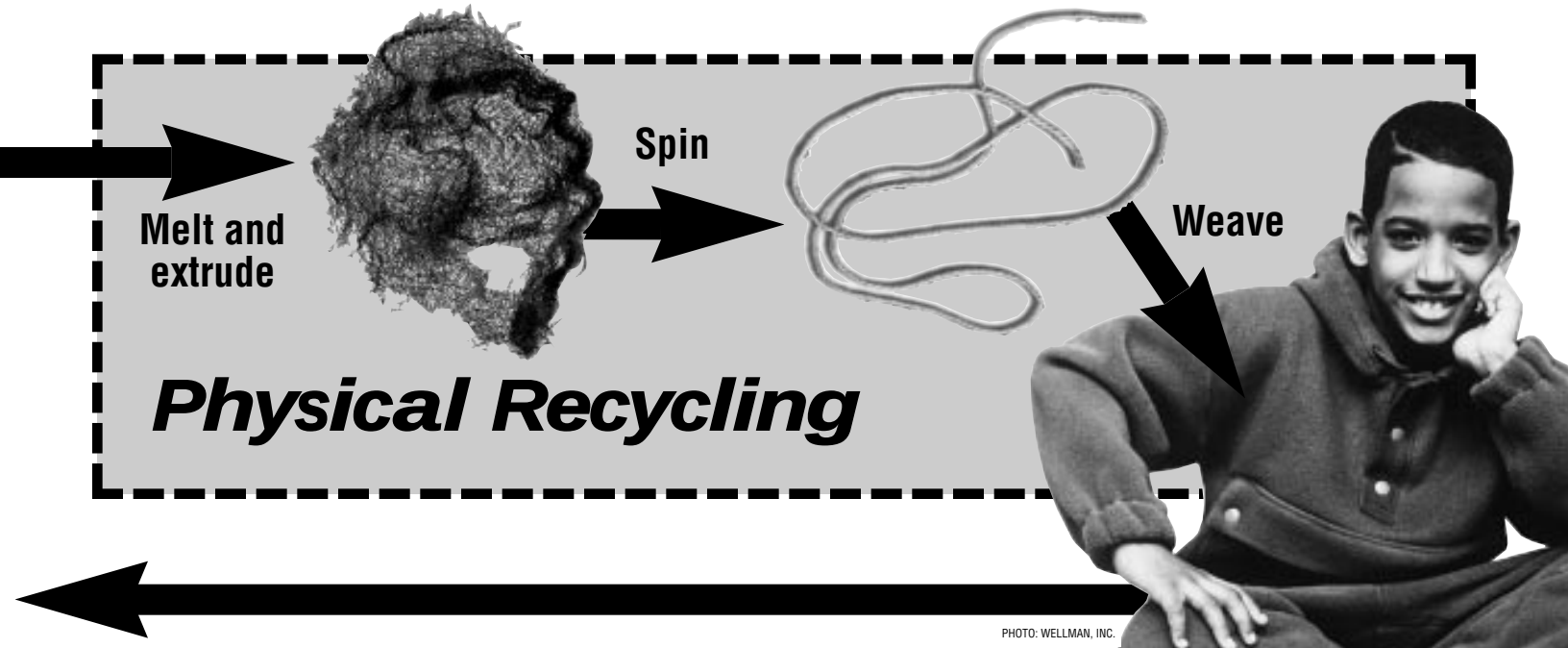


PHOTO: WELLMAN, INC.

This outfit was a winner in a fashion design contest sponsored by Wellman, Inc. All of the contest entries were made of EcoSpun, the company's polyester fiber that is 100% recycled plastic from bottles.

In 1991, DuPont developed a number of demonstration products from polyester. One result was a set of sails made from PET bottles for the Tall Ship, *HMS Rose*. Automobile fenders also have been made of recycled PET. Terrence Cressy, a spokesperson for DuPont Automotive, believes there is "absolutely no limit to product development from recycling plastics." He does not think it unreasonable that engine parts will eventually be made from plastics. "I think we are moving from the age of metals to a polymer age."

That would certainly suit Nathaniel Wyeth, the chemist who is credited as "the father of the plastic soda bottle." Wyeth said, "One of my dreams is that we're going to be able to melt the return bottles down, mix them with reinforcing fibers, and make car bodies out of them. Then, once the car has served its purpose, rather than put it in the junk pile, melt the car down and make bottles out of it."

Just think, one day you might be driving your favorite old T-shirt, or wearing your old car!

Christine Plummer *is a science writer in Baltimore, MD. A previous article written by Ms. Plummer for* Chem Matters *magazine ("Poisoned Milk," December 1992) won the top award from the Society for Technical Communication.*

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PHOTO: MIKE CIESIELSKI

by Gail B.C. Marsella

Chewing just for the sake of chewing has been around for a long time. Eskimos chew whale blubber. People in South and Central America chew various rubbery tree saps. Of all the substances chewed for recreational purposes, however, none has generated as much interest—now more than $150 million annually—as bubble gum. During World War II, in fact, it was so rare and precious that kids sometimes saved and chewed the same piece for weeks.

Bubble gum was invented by Frank Fleer in 1906, but Blibber Blubber, as he called it, stuck to just about anything and wasn't a very good product. In 1928, an employee of the Fleer Corporation named Walter Diemer finally mixed up the first batch of Dubble Bubble, a good, stretchy gum that didn't stick to skin, was easy to chew, and blew good bubbles. Fleer still sells Dubble Bubble, although the basic ingredients are now different. (Diemer has never revealed his original formulation.)

Bubble gum is a mixture of several chemicals, but rubber is the most critical. A good bubble gum must be strong enough to stretch to a thin film without breaking, but still be soft enough to chew easily. That's a tall order. Any type of rubber alone is too firm, but no other material can stretch like rubber. The other chemicals in bubble gum—resins, waxes, fillers, flavors, sugar, humectants, and emulsifiers—are all there either to provide flavor or to modify how and when and how much the rubber stretches.

Any rubber is a polymer, a long chain-like molecule formed when many small molecules bond together end to end. Familiar polymers include nonstick coatings for frying pans, many types of paint, most synthetic fibers, and a variety of biochemicals. Before synthetic poly-

bblegum

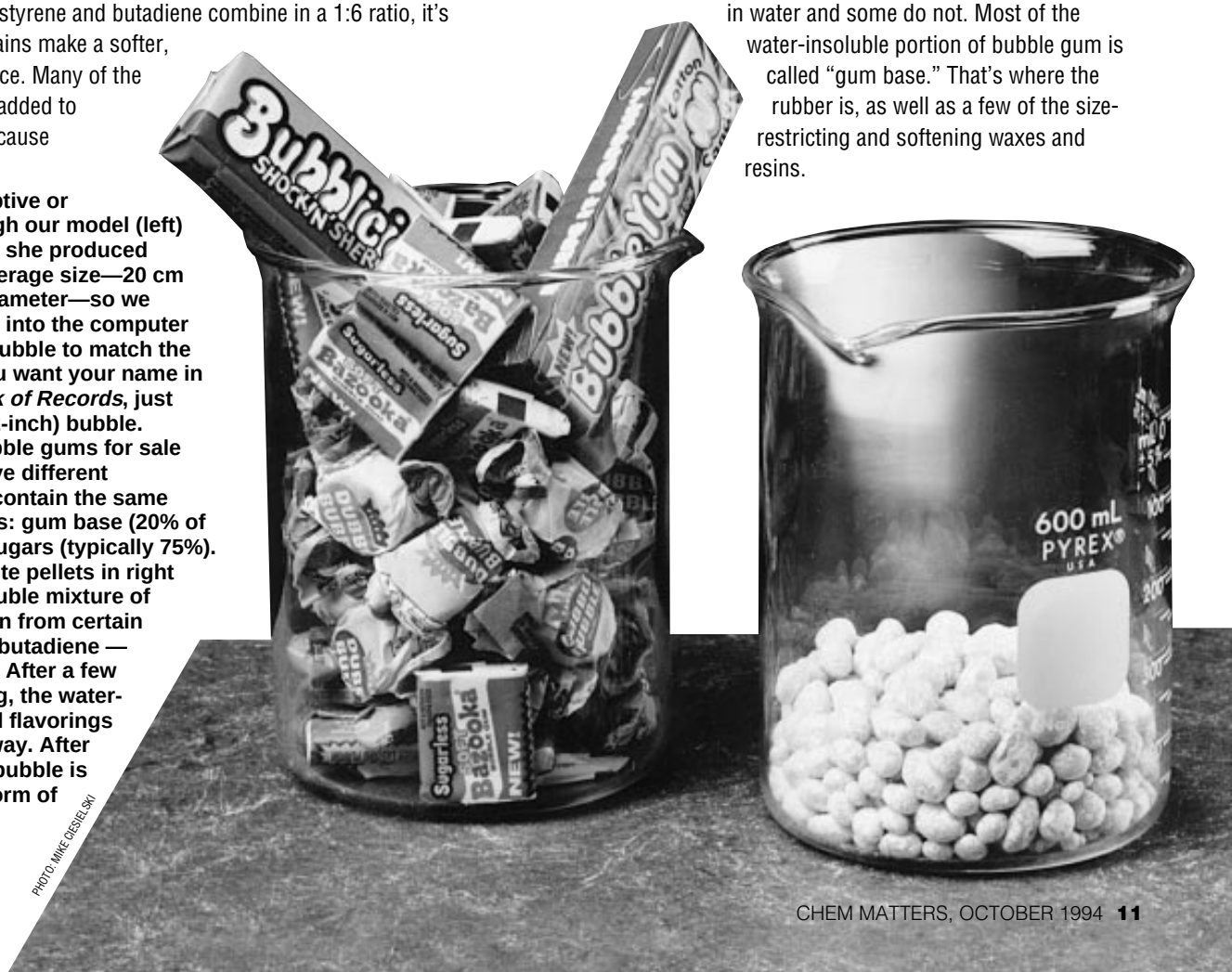
mers became available, natural latex from trees provided the stretchy part of bubble gum. Now many gum manufacturers use a food-grade version of the same rubber that goes into truck tires—a polymer of styrene and butadiene, often abbreviated SBR (see structures on page 12).

The largest bubble ever blown with bubble gum (measured, anyway) was nearly two feet in diameter. Theoretically, if the gum contained enough rubber and just the right combination of other ingredients, you could get a bubble even larger than that. Gum companies have no intention of alienating parents to that extent, however, so they make certain that bubbles break when they get not much larger than a grapefruit.

Like all polymers, some chains are long whereas others are short. However, as long as styrene and butadiene combine in a 1:6 ratio, it's still SBR. Shorter chains make a softer, more pliable substance. Many of the softening chemicals added to bubble gum work because they lower the average molecular weight of the entire mixture.

Some additives in gum restrict the size of bubbles. Think of a big tangle of rubber molecules, like a handful of rubber bands. As the mass stretches, the molecules line up and form a thin layer. If you dilute the rubber molecules with shorter, nonstretchy materials, however, they have a greater tendency to shred apart rather than stretch, and the bubble breaks. The materials used to dilute the concentration of rubber molecules include waxes and resins, the same molecules that can also soften gum. Gum makers are helped in their efforts to restrict bubble size by the air temperature; as any rubber gets colder, it becomes more brittle. The outside air is colder than the mouth, so the bubble loses elasticity as it is blown.

Of the approximately 20 chemicals in bubble gum, some dissolve in water and some do not. Most of the water-insoluble portion of bubble gum is called "gum base." That's where the rubber is, as well as a few of the size-restricting and softening waxes and resins.



Is this photo deceptive or descriptive? Though our model (left) tried her very best, she produced bubbles of only average size—20 cm (eight inches) in diameter—so we scanned her photo into the computer and enlarged the bubble to match the world record. If you want your name in the *Guinness Book of Records*, just beat this 56-cm (22-inch) bubble.

The various bubble gums for sale (photo at right) have different flavorings, but all contain the same primary ingredients: gum base (20% of the product) and sugars (typically 75%). The gum base (white pellets in right beaker) is an insoluble mixture of synthetic wax, resin from certain trees, and styrene/butadiene — a synthetic rubber. After a few minutes of chewing, the water-soluble sugars and flavorings largely dissolve away. After ten minutes, your bubble is just an insoluble form of rubber and resin.

PHOTO: MIKE DIESEL SKI



PHOTO: CLEVELAND INDIANS

In 1992 Kevin Wickander and Steve Olin, then pitchers for the Cleveland Indians, engaged in a bubble gum-chewing contest. After fierce competition they tied—each managed to cram 71 pieces of Bazooka into his mouth.

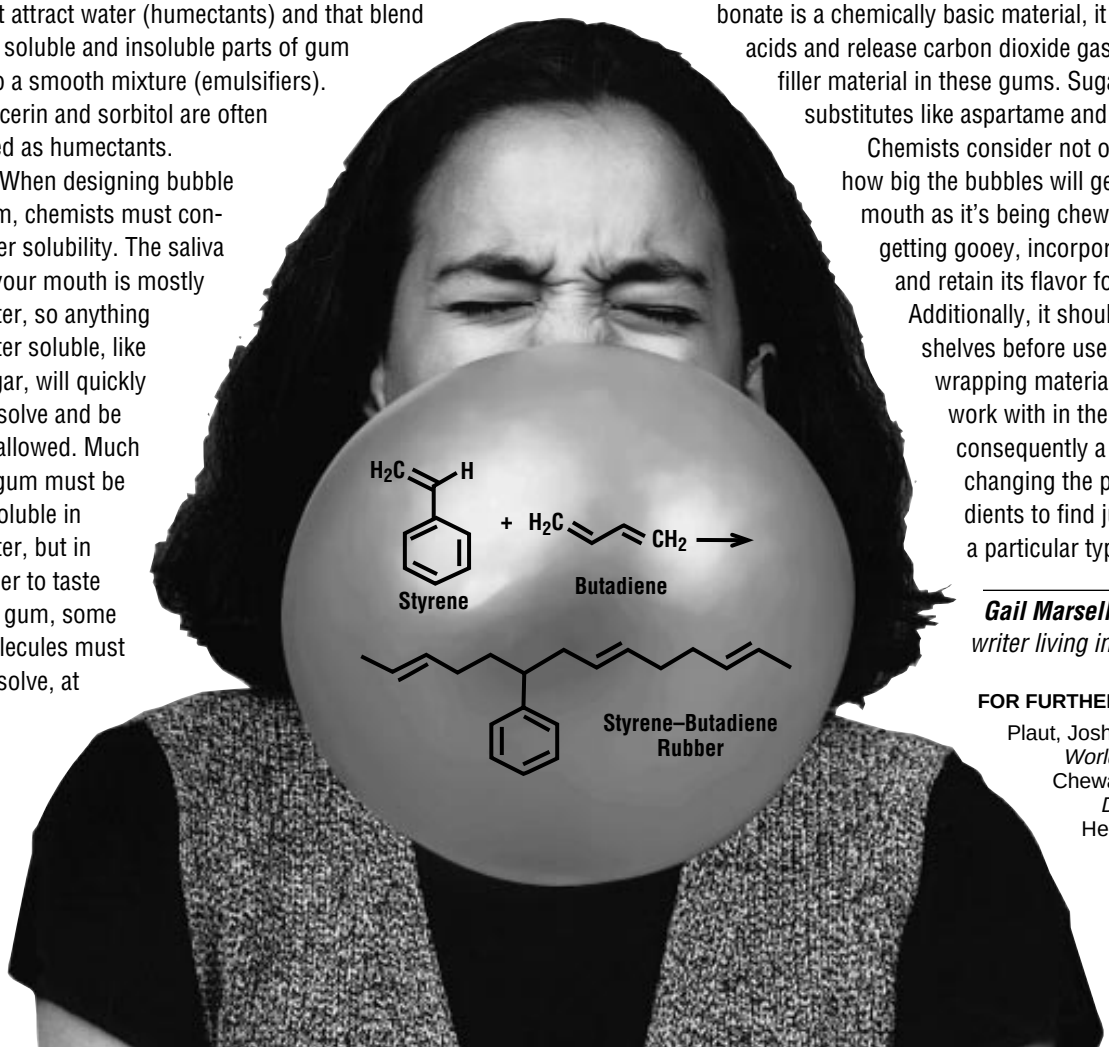
The gum base ingredients are all fairly soluble in each other, so they form a uniform film. Gum base doesn't dissolve in water, so it remains in your mouth after you've chewed out all the water-soluble ingredients. Without water, however, gum base still wouldn't be pleasantly chewable, so gum makers add chemicals that attract water (humectants) and that blend the soluble and insoluble parts of gum into a smooth mixture (emulsifiers). Glycerin and sorbitol are often used as humectants.

When designing bubble gum, chemists must consider solubility. The saliva in your mouth is mostly water, so anything water soluble, like sugar, will quickly dissolve and be swallowed. Much of gum must be insoluble in water, but in order to taste the gum, some molecules must dissolve, at least a little. Water-soluble and water-insoluble materials do not mix well (think of oil and water in salad dressing), so chemists add emulsifiers, molecules that help mix chemically insoluble materials together.

A lot of the ingredients in bubble gum perform more than one function. Flavorings can also soften the gum. Glycerin softens and absorbs water. Sorbitol sweetens and absorbs water. Corn syrup not only softens and sweetens, but also helps bind sugar to the gum base. The waxes and polymers chosen for gum are rather hard at room temperature, but soften considerably at mouth temperature. Calcium carbonate acts as a filler, lowering the cost of the gum.

Different gum products result from adding flavorings, forming the gum into different shapes, and perhaps coating it with candy. The gum base, flavorings, and additives are mixed together in giant mixing machines and then extruded into shapes, or flattened out and cut up into bubble gum tape. The most intense fragrances and flavorings in fruits are often essential oils like limonene, well suited to gum formulation because they are not water soluble and do not dissolve out of gum in the mouth. Gum does seem to lose flavor after a while, but that is usually because of the removal of sugars that intensify the fruit flavor. A relatively new set of products incorporates fruit acids in addition to flavorings to make the gum sour. Because calcium carbonate is a chemically basic material, it would neutralize the fruit acids and release carbon dioxide gas, so talc is substituted as the filler material in these gums. Sugar-free gums rely on sugar substitutes like aspartame and sorbitol for their sweetness.

Chemists consider not only how the gum tastes and how big the bubbles will get, but also how it feels in the mouth as it's being chewed. It must soften without getting gooey, incorporate water without dissolving, and retain its flavor for as long as possible. Additionally, it should not dry out on store shelves before use, it should not stick to the wrapping material, and it should be easy to work with in the factory. Gum formulation is consequently a matter of trial and error, changing the proportions of the many ingredients to find just the right combination for a particular type of gum.



Gail Marsella *is a chemist and freelance writer living in Allentown, PA.*

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IRON for Breakfast

by Karen Schmidt

When you eat a bowl of cereal, you may notice that on the box it says "iron fortified." And if you read the ingredients, you'll see iron listed. For several decades, iron has been billed as important for "building strong bodies" and "curing tired blood." Food companies began enriching flour with iron in the 1940s. Then in the 1960s the U.S. Food and Drug Administration (FDA) decided to allow food companies to iron fortify other products as well: hot and cold cereals, crackers, cookies, infant formulas, and pasta. The goal was to help people with low incomes and poor diets receive more of this vital nutrient. The prevalence of iron deficiency, which can cause developmental delays in children and extreme fatigue in adults, has indeed declined.

But now some scientists are wondering if Americans may be taking in too much iron. The reason for their concern? The same property that enables iron to spur important chemical reactions in the body also makes it dangerous in large doses.



PHOTO: MIKE CIESIELSKI

The label on the package of Total Corn Flakes indicates that it contains 100% of the recommended daily allowance of 12 vitamins and minerals. Most of these nutrients are readily absorbed by your body. However, very little of the iron that is added to the cereal is absorbed because it is in the form of the insoluble metal. For iron, the Recommended Dietary Allowance (RDA) is 10 mg per day for men, 15 mg for women, and 30 mg for pregnant women.

Double-edged sword

Iron has the power to shuttle electrons from place to place, but this power is like a double-edged sword. The metal comes in two oxidation states: Fe^{2+} [iron(II), ferrous] and Fe^{3+} [iron(III), ferric]. Because iron atoms can easily switch between these two forms by gaining or losing an electron, iron compounds can be potent catalysts. Cells, in fact, rely on enzymes with iron, called cytochromes, to transfer electrons back and forth. Ultimately, this process produces ATP, the cell's chemical energy. Also, the hemoglobin in red blood cells relies on ferrous iron to pick up molecules of oxygen from the lungs. The iron and oxygen form a loose covalent bond that is easily broken, so after transport, the oxygen can be released in tissues and organs.

What would happen if there were too much iron in your body? Excess iron in the body leads to a gradual deterioration of organs, such as the liver, pancreas, and heart. Extremely high quantities, such as from an overdose of iron tablets, can "corrode" the intestines and cause death by internal bleeding. (A common cause of death among young children in the United States is eating a toxic dose of adult iron pills.)

Some scientists hypothesize that even slightly higher than necessary amounts of iron in the body can catalyze the production of free radicals, super-reactive chemicals that destructively swipe electrons from other compounds. In theory, these free radicals can damage DNA, causing mutations and eventually cancer. According to Lawrence Loeb, director of the Joseph Gottstein Cancer Laboratory at the University of Washington in Seattle, iron has been found attached to DNA in cells. With regard to iron's potential for causing free-radical damage, he says, "It has not been shown conclusively in the body, but it's highly unlikely that this wouldn't occur."

Ironclad control

The key to handling a double-edged sword like iron is balance. Fortunately, the human body has evolved ways to utilize iron to an advantage, while minimizing its dangers. For example, the human body carefully regulates iron by controlling the amount absorbed from the diet. If the body already has enough iron, the cells lining the intestine receive a signal to block their uptake of iron from food. If the body needs iron, the intestinal cells take it in.

As soon as iron is absorbed from food, it becomes bound to a protein in the blood called transferrin, which carries the iron to where it's needed. Most iron goes to the bone marrow, where it is built into hemoglobin and made into red blood cells. Smaller amounts of iron go to the liver, where it may be turned into enzymes or stored for later use. The body keeps this reactive metal under tight wraps by binding it with various proteins. In this way, the body regulates where iron goes and what it reacts with. During storage, iron is bound to a protein to form ferritin.

"The amount of free iron floating around in most people is trivial—it's always bound to something," says Harold Sandstead, an expert on trace metal nutrition at the University of Texas at Galveston. "If it weren't, we'd all be very sick."

With such elaborate regulatory mechanisms, why worry about getting too much iron? Although most people's bodies do a good job of keeping iron under control, some are born without the usual safeguards against iron overload. About one percent of Caucasian Americans inherit a double dose of a gene that permits excessive iron absorption. In these people, the cells in the gut never shut down their

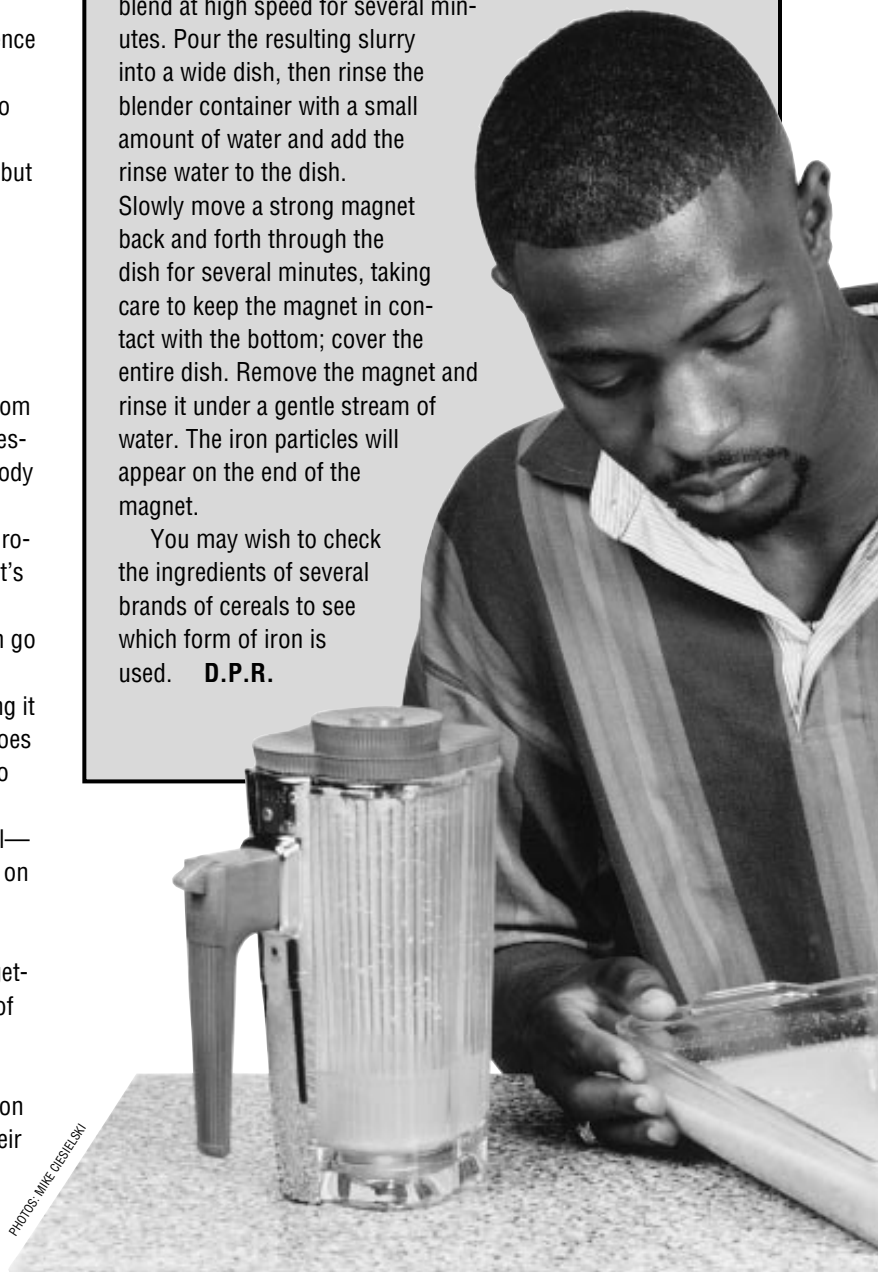
Extracting iron

Iron is added to food to guarantee that you receive enough of this vital mineral. Without adequate iron, your red blood cells would not be able to transport oxygen to your tissues. Each hemoglobin molecule contains an iron ion, and it is this ion that attracts and binds O_2. Lack of iron leads to iron deficiency anemia, a condition of chronic fatigue.

The iron added to breakfast cereal is often contained in $FePO_4$, iron(III) phosphate (also called ferric phosphate), which dissolves in HCl, hydrochloric acid (stomach acid). However, General Mills prefers to add particles of pure iron metal (called elemental iron or reduced iron) to its Total Corn Flakes because elemental iron is stable in storage and does not affect the cereal's flavor. However, very little of the elemental iron dissolves in stomach acid (approximately equivalent to 0.1 M HCl). The iron particles are baked into the Total flakes but you can easily extract them by the following method.

Place approximately 750 mL (about 3 cups) of Total Corn Flakes into a blender and add approximately 500 mL (about 2 cups) of water. Cap the container, then blend at high speed for several minutes. Pour the resulting slurry into a wide dish, then rinse the blender container with a small amount of water and add the rinse water to the dish. Slowly move a strong magnet back and forth through the dish for several minutes, taking care to keep the magnet in contact with the bottom; cover the entire dish. Remove the magnet and rinse it under a gentle stream of water. The iron particles will appear on the end of the magnet.

You may wish to check the ingredients of several brands of cereals to see which form of iron is used. **D.P.R.**



PHOTOS: MIKE DIESELSKI

uptake of iron and the result is the disease hemochromatosis. In Africa, a different gene causes a similar problem. Moreover, once too much iron is taken up, only minuscule amounts are shed from the body.

Scientists aren't sure how common these inherited disorders of iron metabolism are. However, 10 to 15 percent of the population may carry one of these genes, says Munsey Whebe, a hematologist at the University of Virginia at Charlottesville.

Obviously, people with hemochromatosis should steer clear of iron in their diets. They're also advised to donate blood regularly to reduce their body iron. Unfortunately, most people with hemochromatosis don't discover they have the disorder until they reach middle age, when health problems start to occur. The Hemochromatosis Foundation recommends that people who show unusual blood chemistry be tested as young adults to see if they carry one of these genes.

What about people with normal iron metabolism? Are they at risk from too much iron in their diets? Two recent studies have questioned whether there may be a link between high amounts of iron in the body and cancer. Both involved thousands of subjects, who more than a decade ago had their body iron levels measured—actually how much iron was stuck to the transferrin in their blood. The researchers then followed up to see who developed cancer. In both studies, people with the highest amount of body iron were twice as likely to get cancer as people with normal iron levels. Although these results do not prove that iron causes cancer, they are consistent with the theory that when there's too much iron in the body, some of the metal atoms may escape their protein bonds and cause free radical damage to DNA.

Bioavailability

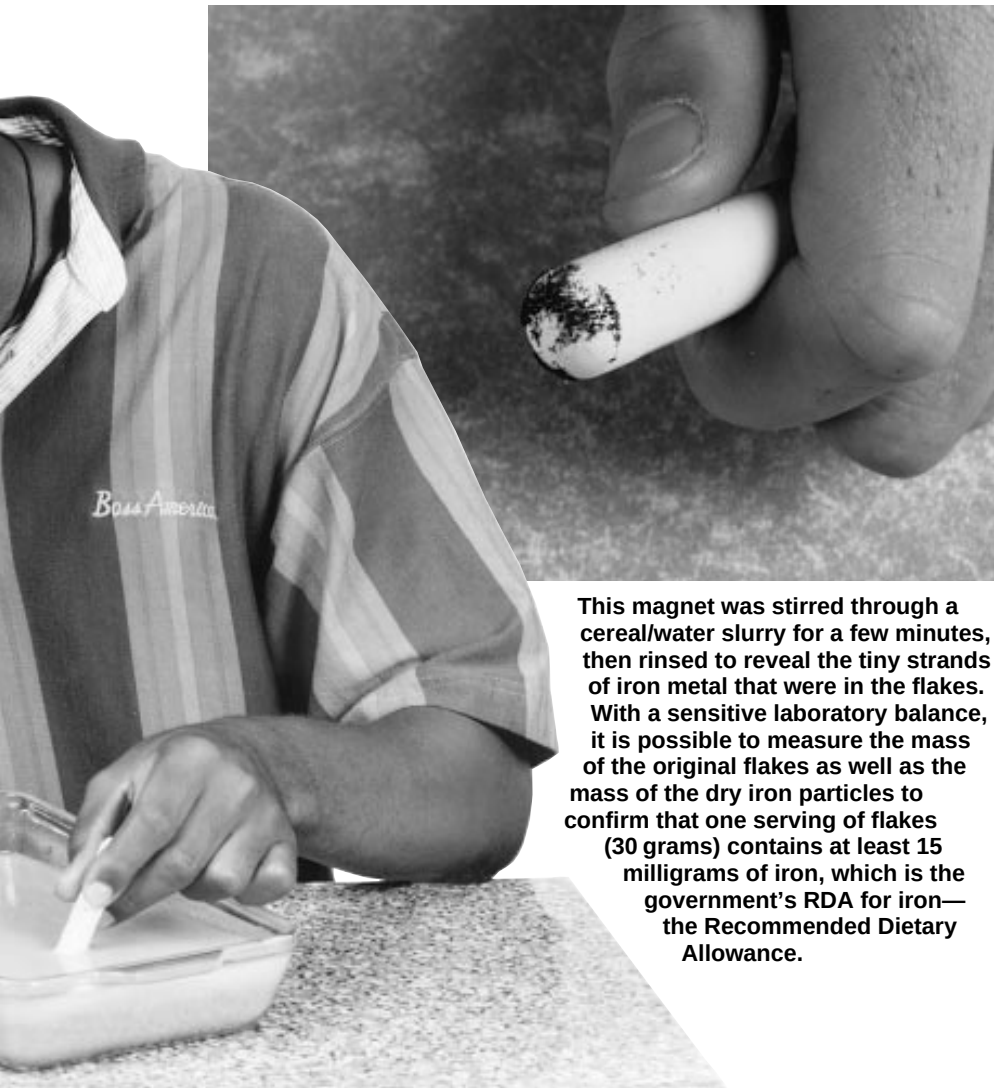
There are many different forms of iron in food and not all are equally useful to your body. For example, iron in the form of iron(II), which is sometimes called ferrous iron, is easier to absorb than iron(III), or ferric iron. And the iron in red meat, which comes already bound to the chemical group called heme, is five times more absorbable than the iron in vegetables. In other words, there's the question of iron's "bioavailability." The iron in some breakfast cereal, in fact, appears to be largely unavailable to the body. Some manufacturers simply add iron filings to the cereal. This "elemental iron" is stable, which doesn't shorten the product's shelf life, but your body cannot absorb it. Elemental iron (oxidation state, zero) must first be oxidized to iron(II) by stomach acid. Researchers have found, however, that your stomach acid can't dissolve most of the iron filings during the limited time the cereal remains in your stomach.

Some products are fortified with iron(II) sulfate (also called ferrous sulfate) because the iron(II) salt is taken up much more readily. Still, if it comes in a high-fiber cereal or if you drink a cup of tea with your meal, much of this iron may also pass out of the body unabsorbed. So, despite the claims on the box, it's quite likely that you will not get 100% of the recommended daily allowance of iron from your breakfast cereal.

Examining the sword

Because iron is like a double-edged sword, the human body has evolved complex ways of handling it. It's no surprise that within the human population, individuals exhibit wide variation in their metabolism of iron—some have a tendency to get too much, whereas others never seem to be able to get enough. The FDA is currently evaluating the body-iron status of Americans. The agency is waiting for additional research data to clarify whether too much iron causes cancer. At this point, however, it has no plans to change its iron fortification policies.

And how do you know if you, personally, are getting the right amount of iron? In general, growing children and women of childbearing age have the greatest need for iron and are more likely to be deficient. Middle-aged men, on the other hand, have a greater tendency toward iron overload. Your doctor can test your blood for the proper iron concentration and also tell you whether you carry the hemochromatosis gene.



This magnet was stirred through a cereal/water slurry for a few minutes, then rinsed to reveal the tiny strands of iron metal that were in the flakes. With a sensitive laboratory balance, it is possible to measure the mass of the original flakes as well as the mass of the dry iron particles to confirm that one serving of flakes (30 grams) contains at least 15 milligrams of iron, which is the government's RDA for iron—the Recommended Dietary Allowance.

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FOR FURTHER INFORMATION:

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It's not Centigrams or Milligrams
It's Anagrams

by Dorothy Mann Lamb, Chicago State University

Each of the words below has a chemistry anagram, a word formed by rearranging the letters of the given word. There is one line for each letter of the word.

(answers are on page 3)

ADORN ___ ___ ___(1) ___ ___

BRUTE ___ ___(2) ___ ___ ___

SHAPE ___ ___ ___ ___(3) ___

MOAT ___ ___(4) ___ ___

DESTINY ___ ___ ___ ___ ___ ___ ___(5)

TRIFLE ___ ___ ___(6) ___ ___ ___

NONE ___ ___ ___(7) ___

CONVERSATION ___(8) ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

ACTION ___ ___ ___ ___ ___(9) ___

CRATE ___ ___ ___ ___(10) ___

REBAKE ___ ___ ___ ___ ___ ___(11)

HATE ___ ___(12) ___ ___

DEAL ___ ___ ___(13) ___

LAST ___ ___ ___ ___(14)

SLIVER ___ ___(15) ___ ___ ___ ___

GROAN ___ ___ ___ ___(16) ___

PRONTO ___ ___ ___ ___ ___ ___(17)

SAG ___ ___ ___(18)



ILLUSTRATION: DAN SHERBO

Copy the numbered letters of your anagram onto the lines below:

___(1) ___(2) ___(3) ___(4) ___(5) ___(6) ___(7) ___(8) ___(9) ___(10) ___(11) ___(12) ___(13) ___(14) ___(15) ___(16) ___(17) ___(18)

Finally, write anagrams of the three words above to find out what chemistry students like to do:

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Answers