

Production Team

Carl Heltzel, *Editor*
Cornithia Harris, *Art Director*
Leona Kanaskie, *Copy Editor*
Michael Tinnesand, *Contributing Editor*

Administrative Team

Terri Taylor, *Administrative Editor*
Sandra Barlow, *Senior Program Associate*
Peter Isikoff, *Administrative Associate*

Technical Review

Seth Brown, *University of Notre Dame*
David Voss, *Medina High School, Barker, NY*

Teacher's Guide

William Bleam, *Editor*
Donald McKinney, *Editor*
Mark Michalovic, *Editor*
Ronald Tempest, *Editor*
Susan Cooper, *Content Reading Consultant*
David Olney, *Puzzle Contributor*

Education Division

Mary Kirchhoff, *Director*
Michael Tinnesand, *Associate Director for Academic Programs*

Policy Board

Doris Kimbrough, *Chair, University of Colorado—Denver*
Ron Perkins, *Educational Innovations, Inc., Norwalk, CT*
Barbara Sitzman, *Tarzana, CA*
Ingrid Montes, *University of Puerto Rico*
Susan Gleason, *Middletown, DE*

ChemMatters (ISSN 0736-4687) is published four times a year (Oct., Dec., Feb., and Apr.) by the American Chemical Society at 1155 16th St., NW, Washington, DC 20036-4800. Periodicals postage paid at Washington, DC, and additional mailing offices. POSTMASTER: Send address changes to *ChemMatters Magazine*, ACS Office of Society Services, 1155 16th Street, NW, Washington, DC 20036.

Subscriber Information

Prices to the United States, Canada, and Mexico: \$14.00 per subscription. Inquire about bulk, other foreign rates, and back issues at: ACS Office of Society Services, 1155 16th Street, NW, Washington, DC 20036; 800-227-5558 or 202-872-6067 fax. Information is also available online at <http://chemistry.org/education/chemmatters.html>.

The American Chemical Society assumes no responsibility for the statements and opinions advanced by contributors. Views expressed are those of the authors and do not necessarily represent the official position of the American Chemical Society. The activities in *ChemMatters* are intended for high school students under the direct supervision of teachers. 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, from ignoring the cautions contained in the text, or from not following standard safe laboratory practices.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means, now known or later developed, including but not limited to electronic, mechanical, photocopying, recording, or otherwise, without prior permission from the copyright owner. Requests for permission should be directed in writing to *ChemMatters*, American Chemical Society, 1155 16th St., NW, Washington, DC 20036-4800; 202-833-7732 fax.



© Copyright 2007, American Chemical Society
Canadian GST Reg. No. 127571347
Printed in the USA



Question From the Classroom

By Bob Becker

Q: I saw a video on the Internet in which this guy drops a bunch of Mentos candies into a 2-L bottle of Diet Coke, and the soda erupts all over the place. It looks like a geyser. I tried it myself, and it really does work. What's going on?

A: In the past six months, I've been asked this question more often than any other in my career... even by people I've just met. So I went online to learn all I could, to see what kind of research has been done and to read what various "experts" say on the matter. A Google search of "Diet Coke and Mentos" (quotation marks included) turns up 305,000 links! After reading all 305,000 links (yeah right), I learned that very little has actually been written to explain the phenomenon and even less has been done to research the question. So I decided to conduct a little back yard research of my own and found some intriguing answers. On the basis of this study and the few authoritative Web sites I could find, here is what I believe to be the explanation:

The amount of CO₂ one can dissolve in a liter of solution depends directly on the pressure of CO₂ pushing down on the solution's surface. In the bottling plant, the CO₂ is pumped in at very high pressures, and therefore a rather high CO₂ concentration is established in the bottles of soda. Once a bottle is opened and the pressure on the soda's surface drops, it creates what is known as a supersaturated solution—under the diminished pressure in the room, the solution is holding more CO₂ than it is supposed to be able to hold. This is unstable, but it is only a temporary situation. The effervescing (undissolving and bubbling out of the excess dissolved CO₂) begins right away, but it is a rather slow process. A newly opened soda bottle will eventually go completely flat, but it can take several hours.

One thing that makes this effervescing go faster is temperature. The higher the temperature, the more quickly the soda will lose its fizz. With this in mind, you might think that adding an ice cube into a cup of freshly poured, room-temperature soda would cool it down and make the fizzing much slower. But give it a try, and you'll discover just the oppo-



MIKE OEBELSKI

site. As soon as the ice cube hits the soda, the effervescing increases dramatically, especially if the ice cube is one right out of the ice cube tray with lots of sharp edges and rough surfaces. This is because of a second factor that can have a huge impact on the rate of effervescing—nucleation sites.

Nucleation site is just a fancy name for "a place to get things started." Small, uneven surfaces give the CO₂ molecules a place to come together and form into bubbles. The bottling companies know about nucleation sites: they make the inside walls of soda cans and bottles extremely smooth and free of any nucleation sites. If these walls were at all rough, the soda would spray out the moment the bottle was opened. In fact, nucleation sites are responsible for the mess that is made by opening a soda bottle right after it has been shaken. The shaking creates millions of microscopic bubbles. These micro-bubbles serve as nucleation sites and cause a quick release of CO₂ the moment the can is opened. Because these bubbles are spread throughout the bottle, the quick effervescing of CO₂ pushes all of the soda above it out of the bottle. If, however, the shaken bottle is allowed to sit undisturbed for

20–30 seconds, these tiny bubbles have time to float their way to the surface, and the bottle can be opened without the mess!

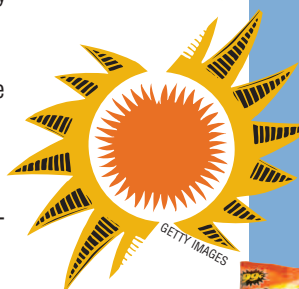
Now, take a close look at a Mentos mint. Its surface is rather dull, not shiny like some candies and, though it feels very smooth to the touch, if we could look at it under high enough magnification, it would show a very rough, pitted surface, with millions of exposed bumps and edges—in short, a nucleation bonanza! And as the Mentos sink to the bottom and degas the soda, the outrushing gas brings a fresh plume of gassy soda in contact with the Mentos, producing more gas, and so on.

The explanation offered above is a purely physical one. Some Web site authors, however, take a more chemical approach. They argue that the geyser effect is the result of the chemical make-up of Mentos—specifically, the ingredient known as “gum arabic,” which supposedly acts as a sort of catalyst to the effervescing. The idea being that the gum arabic (and also coconut oil in the Mentos) is a nonpolar, oily gum that helps the carbon dioxide bubbles to get free because oil and water don’t mix. The water molecules in the matrix become more attracted to each other because they are repelled by the oil, and so it takes less energy for the carbon dioxide to break free. But consider this: When the mints are made smooth by rubbing them repeatedly with a wet paper towel, the fountain effect is cut in half. Also, when the Mentos are dissolved in water and the solution is then poured into a freshly opened bottle of Diet Coke, there is almost no fountain effect at all. Furthermore, the fruit-flavored Mentos have pretty much the same ingredient list as the mint ones, but their surface is much more smooth and shiny, and they produce almost no fountain effect with Diet Coke. Likewise, for the sugar-free mint Mentos. This all leads me to believe that if the explanation does have a chemical component to it, it is a relatively small one and that the greatest factor influencing the Diet Coke and Mentos geyser is that of a pitted surface rich with nucleation sites.

The fact is, I really do enjoy watching this phenomenon and showing it to my students, but perhaps what I like best about it is how easy and fun it is to explore these issues on your own. The opportunities for creative, well-designed experiments are almost endless. ▲



GETTY IMAGES FOR NASCAR



GETTY IMAGES



MIKE GIESIELSKI



UNIVERSITY ARCHIVES, UNIVERSITY OF HAWAII AT MANOA LIBRARIES

CHEM MATTERS®

Vol. 25, No. 1

FEBRUARY 2007

Question From the Classroom

2

What’s up with that Mentos and Coke geyser?

NASCAR: Chemistry on the Fast Track

4

Chemists, start your engines! Get revved up over the science of auto racing. You may be surprised to learn how much chemistry goes down at the track.

Chemsumer

The Sun: Fusion at Work

8

From the dawn’s early light to the twilight’s last gleaming, take a tour through the center of our closest star. Over 15 million K—yow! That’s hot!

Your Colorful Food

12

Green ketchup, apples dyed pink to look like strawberries, and red bugs used to color soft drinks. Was there really such a thing as “sugar of lead?” Take a look at what’s in *your* food.

ChemHistory

Alice A. Ball: Young Chemist Gave Hope to Millions

17

Try to imagine the unthinkable scenario in which you are forcibly removed from your home and deposited in one of the bleakest places on earth. But then, a young African-American woman’s discovery provides you with relief, and maybe a cure—from leprosy!

Chem.matters.links

20

TEACHERS!
FIND YOUR COMPLETE
TEACHER’S GUIDE FOR THIS ISSUE AT
www.chemistry.org/education/chemmatters.html.

CHEMISTRY ON

The Science of NASCAR

By Brian Rohrig

***Drivers,
start your
engines!***

As the green flag descends, 43 cars emblazoned with multicolored decals accelerate to race speed amid the deafening roar of thousands of fans. The smell of rubber permeates the air as the drivers immediately jockey for position. Only one driver will emerge victorious when the checkered flag lowers a few hours and several hundred miles later.

Welcome to NASCAR—the uniquely American sport. NASCAR stands for the National Association for Stock Car Auto Racing, and it began in 1947. NASCAR has exploded in popularity in recent years. It is a dangerous and exhilarating sport. The cars are loud and fast. The drivers are as popular as movie stars. And underneath the hood of every car, chemical reactions are occurring at a furious pace.

The drivers and mechanics who work daily with these cars thoroughly understand the science behind them. And to make things even more challenging, the rules change constantly, sometimes weekly. These constant rule changes force race teams to modify their cars accordingly. And on top of that, each NASCAR track is different, creating the need for

adjustments to be made to the car, depending on the challenges of each particular track.

The skeleton of every NASCAR car is the frame. The frame is tubular and is purchased prefabricated from the manufacturer. It is made of steel tubing—some round and some square. The thickness can vary, but the thickest part surrounds the driver and comprises the roll cage, which protects the driver in case of a collision. The front and rear tubing the thinnest and designed to crush in case of a collision. This protects the driver, as the collapsible frame absorbs the bulk of the energy of a collision, as opposed to the driver. The frame is also designed to force the engine downward and onto the ground in case of a severe collision, and not into the driver.

Every NASCAR car has a few stock parts—hence the name stock car—but these are strictly cosmetic. A stock part is a part that is made in an assembly line by the manufacturer. The only stock parts are the hood, roof, trunk lid, and front grill. The rest of the car is custom made. Each NASCAR car must use stock parts exclusively from one of the following: Chevrolet Monte Carlo, Ford Fusion, Pontiac Grand Prix, or Dodge Charger. Beyond that, the cars bear little resemblance to their namesakes.

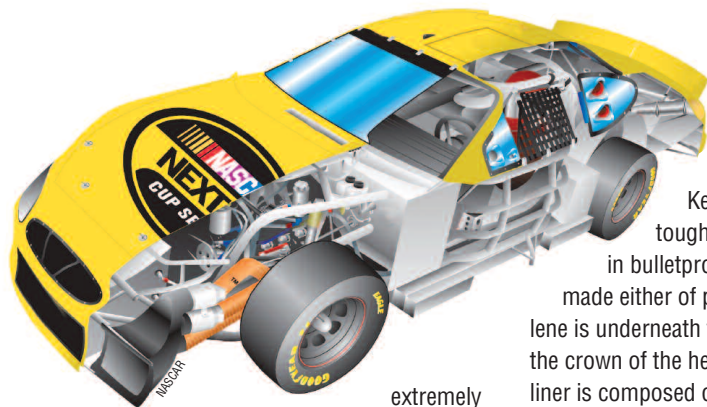
A NASCAR car contains no glass, no doors, no back or passenger seats, no headlights, no brake lights, no speedometer, no gas gauge, no muffler, no stereo, no air conditioning, no glove compartment, no horn, and no air bags! Instead of headlights, stickers are affixed to the front of the car to resemble its parent stock car. The steering wheel is detachable, making it easier to enter and exit the car. You do not need a key to start a NASCAR race car—you simply flip a switch and the engine roars to life.

Playing it safe

Safety is paramount in the construction of every feature of a NASCAR automobile. The windshield is made of Lexan, a very soft but



THE FAST TRACK



extremely durable material. It is so soft that it can be easily dented or scratched, but it will not shatter. It is covered with layers of thin adhesive transparent film to prevent it from being damaged during a race. If a layer of film becomes scratched or dirty during the race, it can be quickly peeled off during a pit stop. Lexan is made from a thermoplastic polymer known as polycarbonate. Thermoplastics soften upon heating. Lexan is also used to make iPods, CDs, and DVDs, and the sturdy water bottles used by hikers. It is so strong that it is the chief component of bulletproof glass!

On the driver's side is nylon webbing in place of a window, which is designed to keep the driver's hands and arms inside the car during a collision. It is equipped with a quick-release mechanism in case a quick exit from the car is required.

All drivers must wear a helmet, which is specially designed for them, and is designed to protect their head in case of an accident.



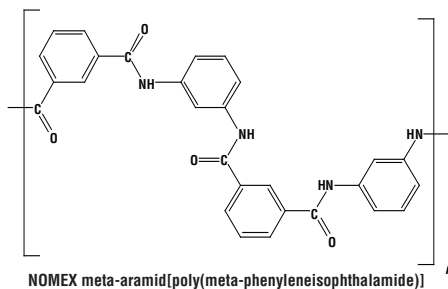
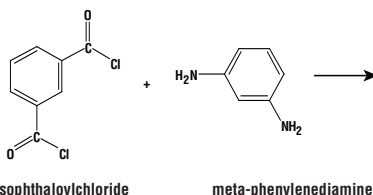
MIKE CHESIELSKI



Cockpit showing head and neck support device.

NASCAR

Racing helmets are made of three main parts. The hard outer shell is coated with a composite of carbon, glass and Kevlar. Kevlar is an extremely tough polymer that is also used in bulletproof vests. A foam liner made either of polystyrene or polypropylene is underneath this layer, and is found in the crown of the helmet. The form-fitting inner liner is composed of either nylon or Nomex, a fire-resistant material. Nomex is also used in firefighters' gear and will not burn even if soaked in gasoline! The chinstraps are made of Kevlar, and the visor is made from Lexan. All helmets are designed to withstand 300 Gs of force.



Synthesis of NOMEX

Drivers are held in place with a five-point harness, similar to that found in a child's car seat. The seats hug the body and are custom made for each driver. They protect the driver's rib cage during an accident. Some seats wrap around a driver's shoulders as well.

After the tragic death of legendary driver Dale Earnhardt in the 2001 Daytona 500, NASCAR mandated the use of a head and neck support (HANS) device to further protect the driver. Earnhardt died due to a fracture at the base of the skull after a 180 mph head-on collision into the wall during the last lap of

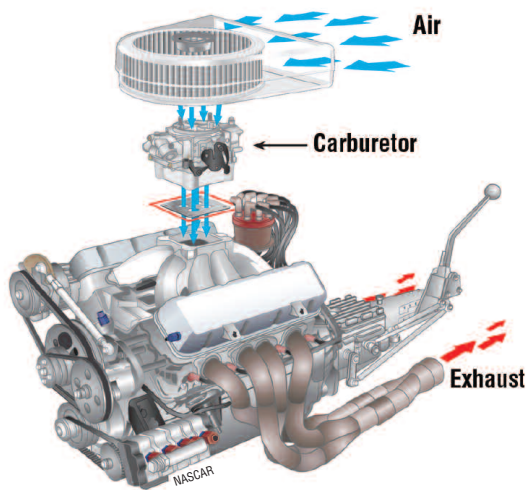
the race. Earnhardt's death could possibly have been prevented if he had been wearing such a device.

The gas tank—fuel cell in NASCAR terminology—generally holds 22 gallons of gasoline. It is composed of an inner elastic bladder made of a thermoplastic elastomer surrounded by an outer layer of steel. The term *elastomer* is often used interchangeably with the term *rubber*. Elastomer comes from two terms: *elastic* (describing the ability of a material to return to its original shape when a load is removed) and *mer* (from polymer, in which *poly* means *many* and *mer* means *parts*). The tank is filled with polyurethane foam, which prevents the fuel from sloshing around. In case of an explosion, the foam would absorb some of the impact. In case a car does burst into flames, the driver is protected. All drivers wear fire-retardant long underwear, as well as a fire-resistant jumpsuit and gloves made from Nomex.

Most cars are equipped with a cooling system that blows cool air into the driver's helmet and over his body. Sometimes, dry ice (solid carbon dioxide) is used in the car, which greatly increases the rate of cooling of the air flowing over it. This constant stream of air cools the driver through the endothermic process of evaporation. Evaporation of water absorbs energy, so when sweat evaporates, it removes energy from the skin, creating a cooling effect. Sweating does not cool you if it cannot evaporate, explaining why it feels so uncomfortable during days of high humidity when little evaporation can occur because the air is already saturated with water vapor. Without these cooling systems, temperatures could easily reach 150 °F (66 °C) within a car during a race.

The engine

The soul of every NASCAR car is its engine. NASCAR cars have 8 cylinders, as do the largest and most powerful passenger vehicles. A cylinder is a space within an engine where the piston moves up and down. You can tell how many cylinders an engine has by the number of spark plugs. Each cylinder contains one spark plug. If the 8 cylinders are arranged in a "V" pattern, the engine is a V-8



Eight-cylinder V8 engine.

(which has nothing to do with the vegetable juice). The V shape is designed to reduce engine vibration, as the vibrations that the pistons produce are cancelled out through destructive interference. The V shape maximizes this destructive interference, thus reducing engine vibration.

The volume of each cylinder is known as its displacement. You may recall from your geometry class that the volume of a cylinder is found by the formula $V = \pi r^2 h$. By adding up the total volume of all the cylinders in the car, the total displacement of the engine is determined, which is commonly referred to as the engine size. A typical NASCAR car has an engine displacement of anywhere from 5735 cc to 5867 cc (350 to 358 cubic inches). That means each cylinder has a displacement of 717–733 cc—a little smaller than a 1-L bottle.

1 cubic centimeter = 1 cc = 1 cm³ = 1 mL

Within each cylinder is a piston, which is a rounded piece of cylindrical metal specially fitted to move up and down rapidly within the cylinder. As the cylinder moves upward, any gases within the cylinder are compressed. As the cylinder moves downward, the gases within the cylinder expand. Boyle's Law states that as the pressure on a gas increases, its volume decreases, and likewise as the pressure on a gas decreases, its volume increases.

Attached to a piston is a connecting rod, which is attached to the crankshaft. The crankshaft rotates very quickly. So the up-and-down motions of the pistons are converted into the rotational motion of the

crankshaft, which is what ultimately causes the tires to spin. The faster the pistons move up and down, the faster the crankshaft rotates. And the faster the crankshaft rotates, the faster your car goes. So to get a 3400 lb (1545 kg) NASCAR race car up to a speed of 200 mph (321 kilometers per hour), those pistons must be moving up and down very fast.

Burn, baby burn

What causes the pistons to move up and down within the cylinders? That's where chemistry comes into place. A mixture of fuel and air within each cylinder is ignited by a spark from the spark plug. As the fuel combusts, it undergoes a chemical reaction, yielding gaseous byproducts. Gasoline can only burn if it is in the vapor state; technically, liquid gas-

muffler, it takes longer to exit the car, reducing the amount of power.

Don't come knocking

What type of fuel do these engines use? Unlike Indy race cars, which use pure methanol (CH₃OH), NASCAR race cars use gasoline, but not the same type that your car uses. They use leaded 110-octane gasoline. The lead is in the form of a compound known as tetraethyl lead (Pb(CH₂CH₃)₄), which reduces engine knocking. Knocking is the loud, metallic clanging that accompanies preignition of fuel in the cylinders before the proper time. Under certain conditions, as gas is compressed in the cylinder, it may ignite before the spark plug fires. A small amount of Pb(CH₂CH₃)₄ improves the performance of the gas, preventing it from igniting as it is compressed. Before the 1970s, almost all of the gas in the United States was leaded, but



An average pit stop involving the changing of all four tires and a full tank of fuel can take between 13 and 15 seconds.

line doesn't burn, it is the vapor above the liquid that burns. The chemical equation for the combustion of the octane within gasoline is as follows:



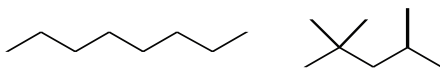
The reaction is also highly exothermic, causing these gases to expand greatly. This expansion pushes against the piston, causing it to move downward. Each of the following eight cylinders will then fire, and once all eight cylinders fire, the process repeats itself over again. These cylinders fire hundreds of times per minute, in rapid succession. NASCAR cars do not have a muffler, explaining why they are so loud. If the exhaust has to pass through a

Pb(CH₂CH₃)₄ is now outlawed in the United States and many other countries as a gasoline additive because it is an environmental contaminant that has been linked to a wide range of neurological and other disorders (*ChemMatters*, 1983 Vol. 1(4)). NASCAR officials have announced a plan to switch to an unleaded high octane formulation by 2008.

The octane rating you see posted on a gas pump such as 93 Octane or 87 Octane is determined by a formula that represents the average resistance of the gas to engine knock. Another way to look at it is the rating tells you how much the fuel can be compressed before it will spontaneously ignite. The higher the octane rating, the more gas can be compressed in the cylinders before ignition. The

more fuel is compressed, the more fuel is burned per unit time, which means more energy is released, and that means more *power!*

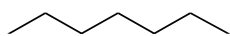
Octane, C_8H_{18} (sometimes called *n*-octane or normal octane), is a hydrocarbon that can be compressed fairly well without igniting. Isooctane, an isomer of octane, is even better at being compressed without igniting, so it is used in regular gasoline and is given the value of 100 in the octane rating system.



n-octane (C_8H_{18})

isooctane (C_8H_{18})

The other major component of gasoline is *n*-heptane, and it is assigned an octane rating of 0. An octane rating of 87 means the mixture has the same resistance to preignition or that it will burn as rapidly as a mixture of 87% isooctane and 13% *n*-heptane.



n-heptane (C_7H_{16})

Why does isooctane resist preignition better than octane? Well, isooctane is a more stable compound than octane, so the combustion of isooctane requires greater activation energy than for *n*-octane. Therefore, isooctane is less likely to ignite due to increased pressure alone.

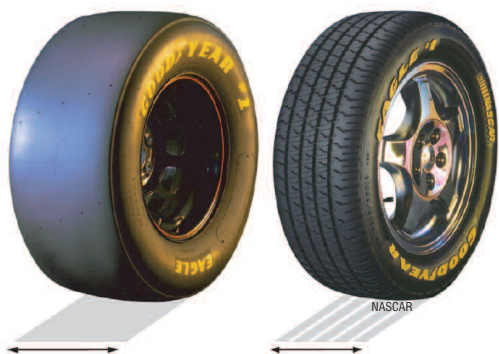
So how in the world can race cars use a fuel with an octane rating of 110? Does this mean you can have 110% isooctane in your fuel? That would be impossible! This high octane rating refers to the performance of the gasoline compared to 100% octane. 110-octane fuel gives a performance 10% better than fuel containing 100% octane by using a high percentage of isooctane and a combination of other additives, including tetraethyl lead.

Tires

Tires play an integral role in any NASCAR race. A typical car can go through 40 tires in one race! The tires are very thin—only about a quarter of an inch thick. If they were any thicker, they would get too hot due to friction between the tire and the track and would melt. Another difference between these tires and normal passenger tires is that NASCAR tires have no tread. They are completely smooth. The smooth surface means

more surface area is in contact with the road, producing better traction. The tires actually become so hot that they do melt slightly, becoming sticky, which further increases traction.

The tires are often underinflated when they are first installed on a car, and after a few laps, the tires heat up and the pressure becomes greater. Tires can experience an increase in pressure of 10–20 psi (pounds per square inch) during a race! This is in accordance with Gay-Lussac's Law, which states that the pressure of a gas increases as its temperature increases. As the temperature goes up, the kinetic energy of the particles increases, which increases the number of collisions and thus the pressure. Even when hot, the tires will generally be under lower pressure than you will find on a typical passenger car, so as to increase the surface area of the tire in contact with the road, further increasing its grip. Because the tires have no tread, a typical NASCAR race cannot be held in the rain or the cars would have no traction whatsoever.



Goodyear Eagle Radial Race Tire
Tread Width: 11.5 inches
Average Life: 150 mi

Goodyear Eagle High-Performance Street Tire
Tread Width: 9 inches
Average Life: 50,000 mi

Another difference between NASCAR tires and normal tires is that NASCAR tires are filled with nitrogen, not normal air (Question From the Classroom, *ChemMatters* February 2006). Compressed nitrogen contains less moisture than normal air. As the tires become heated during the race, any moisture in the tire can vaporize and expand, causing a noticeable increase in tire pressure. Changes in tire pressure can greatly affect the handling of a car. Using normal air that has been dried is another way to reduce moisture content in the air, but this is more difficult to accomplish



GETTY IMAGES FOR NASCAR

than just using compressed nitrogen. Despite these precautions, blowouts do occur. To prevent cars from careening out of control during a blowout, most NASCAR tires contain an inner liner that allows the car to make a controlled stop.

And the winner is ...

When the checkered flag lowers and the race is over, the winner will invariably thank his entire team for winning the race. Behind every driver is a successful crew. The chemistry between the driver and his crew is every bit as important as the chemistry that goes on under the hood. ▲

REFERENCES

- Burt, William. *Behind the Scenes of NASCAR Racing*. Motorbooks International: St. Paul, MN, 2003.
- Miller, Timothy and Milton, Steven. *NASCAR Now*. Firefly Books, Inc.: Buffalo, NY, 2004.
- Van Valkenburgh, Paul. *Race Car Engineering and Mechanics*. Paul Van Valkenburgh: Seal Beach, CA, 2000.

OTHER REFERENCES CAN BE FOUND IN THE TEACHER'S GUIDE FOR THIS ISSUE.

Brian Rohrig teaches at Jonathan Alder High School in Plain City, OH. His most recent *ChemMatters* article, "Thermometers," appeared in the December 2006 issue.



ACS STOCK ART

THE SUN

Fusion at Work



By Clair Wood

Throughout the ages, people have worshipped the Sun as the giver of light, warmth, and life. They instinctively knew that the seasons were somehow controlled by the Sun's movements and, from the Neolithic to the Bronze Age, elaborate monuments were built to track equinoxes, solstices, eclipses, and other solar events important to their lives and religious beliefs. The best known, Stonehenge, was built over a period of 1500 years by three separate cultures. The ancients also spent a great deal of time trying to understand the nature of the Sun. What made it work? As civilizations became more sophisticated, elaborate mythologies grew up around the Sun. To the Egyptians, the Sun was Ra, the god of life, who ruled the seasons and day and night. The Greeks named the Sun Helios, who rode his golden chariot across the sky daily and disappeared beneath the waves at night. The Roman's Sun god, Sol, was described pretty much as the Greek's Helios.

Early theories of the Sun

The first attempts to describe the Sun in other than mythological terms were made by the Greeks. Anaxagoras, a Greek philosopher

born about 500 BC, described the Sun as a great ball of molten iron, an idea likely stemming from his having observed the impact of an iron-nickel meteorite and thinking it to be a piece of the Sun. He also described the Sun as a mass of blazing metal that had been torn from the Earth and ignited by rapid rotation.

When the theory of chemical combustion came into being through the efforts of Antoine Lavoisier and others in the 18th century, it was soon applied to the Sun. One popular theory was that the Sun was a gigantic chunk of burning coal, but this was quickly seen as unworkable when calculations showed the Sun would burn out in a few thousand years.

In 1854, the German physician and physicist Hermann von Helmholtz proposed that the Sun was powered by the conversion of gravitational energy into heat as it collapsed upon itself under its own weight. He calculated that the Sun's lifetime would be on the order of 20 million years. Lord Kelvin redid the cal-

culations in 1887 and extended the Sun's lifetime to 30 million years if it were producing the observed amounts of energy by contraction. However, geologists insisted the Earth was hundreds of millions of years older than Kelvin's figure, and it made no sense that the Earth could be older than the Sun. Also Darwin's theory of evolution by natural selection required a far older Earth and Sun than accounted for by contraction. By 1900, scientists knew that the contraction theory had serious flaws, but no serious alternative surfaced until decades later.

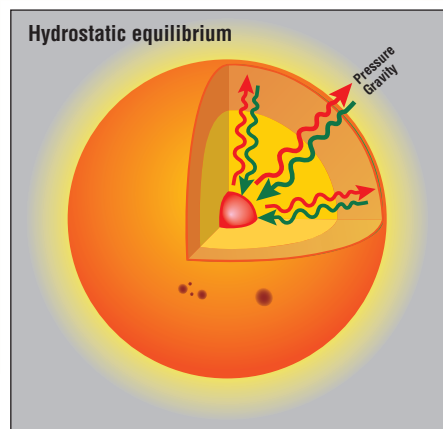


Stonehenge is one of over 40,000 megalithic sites across the British Isles.

Sun's nuclear furnace

It turns out that the contraction theory works up to a point. In young stars, contraction causes heat and pressure to build up. Eventually, both of these build to the point of so-called "nuclear ignition," where the nuclei of hydrogen atoms begin to join or fuse together to form the nuclei of heavier elements. This process releases tremendous amounts of energy—the missing source of energy that was unknown in the 19th century.

Once the nuclear fusion begins, a balance between gravitational contraction and expansion due to heating from fusion is established, which eventually halts contraction. This balance of forces, called hydrostatic equilibrium, keeps the star's volume fairly constant.

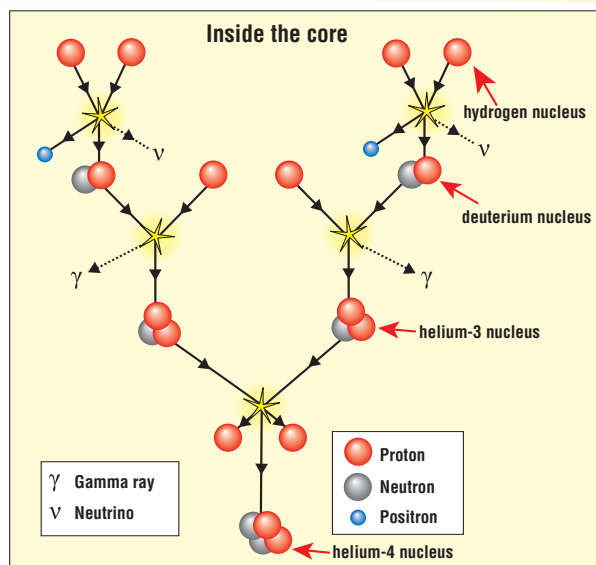


Hydrostatic equilibrium is the reason stars don't implode or explode.

In the case of the Sun, the major element produced is helium. The conditions at which the natural repulsive forces of positive nuclei can be overcome and forced to join together are tremendous. Here are a few facts about the Sun to show the conditions that bring about the nuclear fusion or "burning" of hydrogen to helium. The Sun has a radius 109 times that of the Earth and weighs about 333,000 times as much or roughly 2×10^{27} tons. Over 1.3 million Earths would fit into it. The Sun makes up nearly 99.8% of the mass of the solar system with Jupiter making up most of the rest. As impressive as its mass is, it is the Sun's temperature and pressure that caused nuclear fusion to begin in the core of the Sun. The temperature at the core is estimated to be 15.5 million Kelvin. Sir James Jeans, British physicist and astronomer, in his book *The Universe Around Us*, writes that a pinhead at this temperature would radiate enough heat to kill a man 100

miles away! The core pressure is about 230 billion times standard atmospheric pressure on Earth at sea level.

In 1938 German-American physicist Hans Bethe and others determined that the conditions in the core of the Sun were sufficient to fuse smaller nuclei together into larger ones. Bethe initially proposed that a chain of events brought about fusion: Four hydrogen nuclei fused to form a helium nucleus, involving carbon, nitrogen, and oxygen as intermediates. Later, American physicist Charles Critchfield showed that the pathway proposed by Bethe actually did not occur to a significant extent in the Sun's core. It is simply not hot enough. Instead, the nuclei fuse directly in what is known as the "proton-proton" fusion cycle.



The proton-proton fusion cycle.

The fusion cycle begins when two protons, or hydrogen nuclei, collide to form a nucleus of deuterium (^2H). This fusion is accompanied by the conversion of a minute amount of mass into energy—a lot of energy. In fact, it is enough energy to cause one of the protons to be converted into a neutron, releasing energy in the form of a positron (β^+) and a neutrino (ν). The positron annihilates an electron, and two gamma rays (γ) are created (this is omitted from the figure for clarity). The deuterium combines with another proton forming a helium-3 nucleus (^3He), releasing a gamma ray in the process. Then two ^3He nuclei fuse together to form a normal helium nucleus (^4He), ejecting two protons, which start the process over again.

The proton-proton cycle described by Bethe does take place in larger stars and, to a

minor extent on the Sun. In 1967, Hans Bethe was awarded the Nobel Prize in physics for his discoveries of how energy is produced in the stars. It has been calculated that the high-energy gamma rays produced in this reaction take millions of years to find their way out from the core of the Sun because of repeated scattering. Each collision reduces their energy, and they finally emerge from the Sun's surface in the form of light and heat.

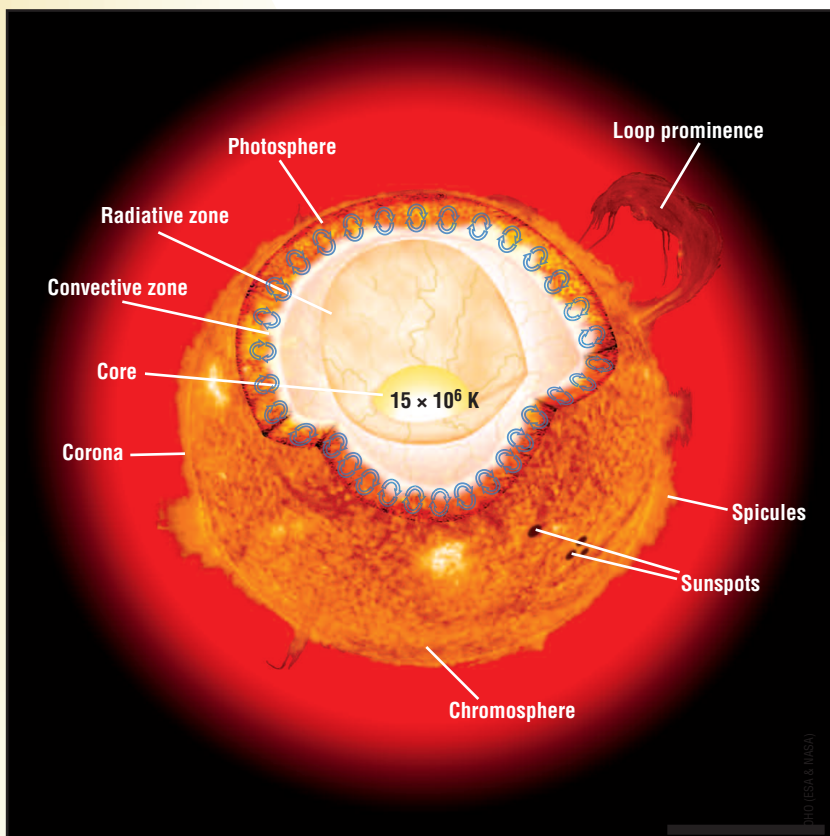
Spectroscopy reveals that the Sun is made up of hydrogen (73.5%) and helium (24.8%), with the remainder being only a smattering of the elements oxygen, carbon, neon, nitrogen, magnesium, iron, and silicon. It is interesting to note that helium was discovered on the Sun before it was found on Earth. In 1868, British scientist and

astronomer Norman Lockyer found the spectral lines of an unknown element in the Sun's spectrum and named the element helium after the Greek god Helios. In 1895, William Ramsay, the Scottish chemist found helium in the mineral uraninite and verified that it had the same spectrum as the element Lockyer observed on the Sun.

Tiny mass loss, huge energy gain

The end result of the proton-proton pathway is that four hydrogen nuclei are fused

together to form helium accompanied by the loss of a small amount of matter and the release of a tremendous amount of energy. The Sun converts 564 million tons of hydrogen to 560 million tons of helium every second with the equivalent of 4 million tons of mass being transformed to energy. If the mass loss is substituted into Einstein's famous equation for the relationship between mass and energy, $E = mc^2$, (where c is the velocity of light), a fantastic amount of energy results. Even the conversion of a tiny amount of mass releases a gigantic amount of energy, as the equation requires the speed of light, 3×10^8 m/s, to be *squared*! The complete conversion of an object with a mass of 1 gram would release 90 trillion joules of energy. That is roughly equivalent to the energy released in the explosion of 20,000 metric tons of TNT.



The radiative zone includes the inner approximately 85% of the Sun's radius, so technically it includes the core.

Convective zone

The method of energy transport that characterizes the convective zone is, you guessed it—convection! Energy is transported via rising and falling gas that extends from a depth of about 200,000 km up to the visible surface. Sunspots and other solar phenomena are generated here.

Photosphere

Next comes the photosphere, a shell of gas about 100 km thick with a temperature of 4500 K to 6000 K. The photosphere is where the solar absorption spectrum, i.e., “what you see,” is produced when observing the Sun. This is also where sun spots, cooler regions of the solar atmosphere at a temperature of approximately 4000 K and associated with intense magnetic fields, are located. The surface of the photosphere appears to be granulated because convection produces cells of gas moving at speeds up to 15,000 miles per hour. They rise up from the interior in the bright areas, spread out along the surface, and then sink inward as they cool.

Chromosphere

The chromosphere is a thin, pink layer of gas seen only during a total solar eclipse when the Moon blocks the photosphere. It reaches a depth of over 6,000 miles and varies in temperature from 6000 K at its boundary with the photosphere to 20,000 K at its upper edge. The chromosphere is the origin of prominences, filaments of gas projecting from the Sun to heights of 15,000 miles, and spicules, which are streams of extremely fast-moving streams of gaseous matter erupting outward along magnetic lines of force.

Corona

The corona consists of diffuse charged particles, or plasma, that extends for millions of miles into space and has a temperature range of between 500,000 K to 2 million K. At these high temperatures, both hydrogen and helium are completely stripped of their electrons. Even the minor elements carbon, nitrogen, and oxygen are stripped down to bare nuclei. Only the heavier trace elements, like iron and calcium, are able to retain a few of their electrons in this intense heat. This is where the plasma comes from. The rise in

According to one author, the energy output in one second by the Sun would supply the entire energy consumption by the United States for 1 million years.

Luckily, only one two-billionths of the Sun's energy reaches the Earth. Otherwise, we would all be cooked to a cinder! Even though the Sun is losing mass at a rate of 4 million tons per second, it is so massive that Isaac Asimov, in *Asimov's Guide to Science*, estimates it has lost only 1/40,000 of its mass since it became a star. The Sun has been around for at least 5 to 6 billion years, and it will last for at least as long again before entering its death throes as a red giant expanding in size to beyond the orbit of Earth, which will be vaporized. Finally, the dying Sun will cool, collapse, and eventually become a white dwarf.

Sun's structure

The Sun consists of its core where nuclear fusion takes place and regions of gaseous layers collectively known as the solar atmosphere. The regions are differentiated by the various processes that take place in them.

Core

The core is essentially a fusion reactor that is stabilized by gravity. Immense amounts

of energy are generated as hydrogen is converted into helium. Helium has an average atomic mass of 4.0026 amu, and the atomic mass of hydrogen is 1.0079 amu. Four hydrogen atoms taken together have a mass of 4.0316 amu. This 0.029 amu difference is the m in Einstein's equation $E=mc^2$. The almost incomprehensible energy released drives the temperature in the core up over 15 million Kelvin. As temperature is related to the kinetic energy of the particles, these particles have a tremendous amount of energy and are moving very fast. Under the extreme pressure in the core, these high-velocity particles slam into one another and become fused. The energy generated is spread outward by radiation and convective fluid flow.

Radiative zone

Right above the core lies the radiative zone. The energy generated in the core is transported by light (photons) through this zone by radiation. The photons undergo countless absorption and emission processes being randomly scattered in the process. This action, known as the “random walk process,” results in its taking up to a million years for a photon generated in the core to reach the surface of the Sun. Once free of the Sun, a photon reaches Earth in less than nine minutes.

temperature here is worth noting because, normally, as you move away from a source of heat, the temperature decreases. The core is about 15 million K, and as you move outward, the temperature drops to about 6000 K in the chromosphere. Then the temperature shoots through the roof in the corona. The cause of the extreme temperatures is a mystery but is thought to be linked to electric currents generated by intense magnetic fields and the Sun's rotation.

Sun-Earth interactions

The Sun interacts with the Earth by several means other than that of providing warmth and light through electromagnetic radiation. The solar wind is a stream of charged subatomic particles, mostly protons and electrons that flow from the Sun at speeds of over 2 million miles per hour. Solar flares are intense, relatively short, bursts of matter and energy, likely due to the sudden release of magnetic energy in a small volume of the solar corona.

Coronal mass ejections (CMEs) are associated with solar flares and are described as gigantic magnetic bubbles. They can contain between 5 and 50 billion tons of ionized gases, breaking from the surface of the Sun with energy equivalents of up to 2 billion megatons of TNT, hurling charged particles toward Earth at speeds of over 2 billion miles per hour (1/3 the speed of light). Besides wreaking havoc with electronics, they are behind the production of spectacular auroras or Northern and Southern lights. Another area of the Sun's internal workings that have been studied a great deal are sunspots. Sunspots are regions of the photosphere that are about 2000 K cooler than their surroundings. They arise from the twisting and tangling of magnetic lines of force, much like tangling strands of string that eventually break through to the Sun's surface. Sunspot activity seems to run in 11-year cycles that range from peak activity to quiet and back again. We are presently near the low-point of the current cycle. For reasons not fully understood, the solar cycles appear to have an effect on Earth's weather. An example is the Maunder Minimum, a time of little to no sunspot activity during 1645–1715 that was concurrent with the "Little Ice Age," a period of extremely cold weather in Europe and North America from the late 1600s to early 1700s.

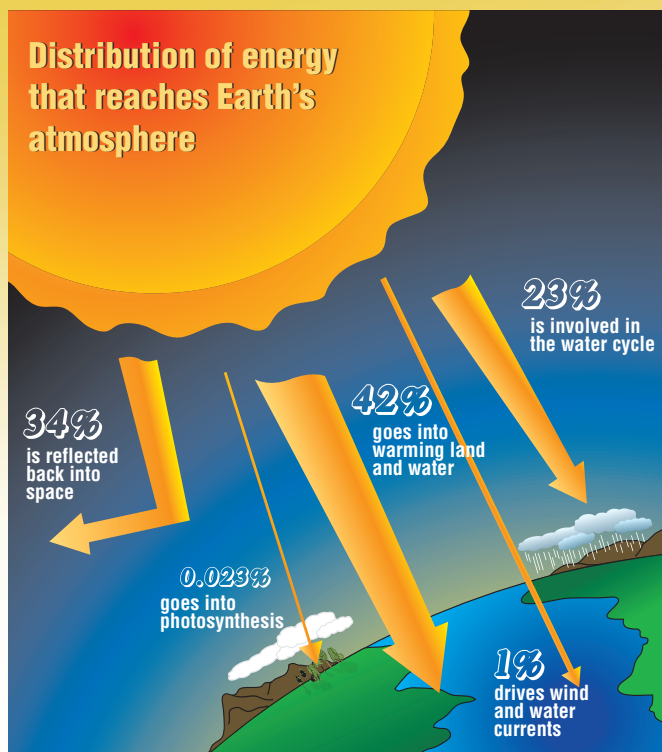
A report issued in March 2006 by the National Center for Atmospheric Research (NCAR) predicted that solar storm activity will increase starting in 2007 and last until 2012. During that period, we can expect occasional disruptions in cell phone service, TV signals, and global positioning systems, as satellites may incur damage. Power surges may cause power grids to crash causing major blackouts.

Using solar energy

The amount of radiant energy reaching the Earth's atmosphere per unit area per second is called the solar constant, and it averages about 1370 joules per meter squared per second ($1370 \text{ J/m}^2 \cdot \text{s}$). The Earth's surface does not get the full benefit of this energy influx, which is roughly distributed as follows: 34% is reflected back into space by snow and clouds, 42% goes into warming land and water, 23% gets involved in the water cycle of evaporation and precipitation, and 1% drives the wind and ocean currents. An estimated 0.023% goes into photosynthesis that is ultimately responsible for life on Earth. Even though only a minuscule fraction of the Sun's total energy output reaches the Earth's surface, it still represents an impressive amount of energy.

Photovoltaic cells generate electricity directly from sunshine, without generating greenhouse gases in the process. In October 2006, the Australian government announced its plans to build the world's biggest solar power station. It will use high-performance solar cells that were originally developed to power space satellites. Fields of mirrors will concentrate and focus sunlight onto the cells in this 154-megawatt (MW) power station.

When most people think of solar power, roof top panels come to mind, but in California and other states, there is another type of solar power plant. The solar energy generating system (SEGS) uses a solar thermal system instead of photovoltaic cells. The system is



based on a parabolic trough of curved mirrors connected in a huge array. A closed-loop tube filled with oil is warmed by the Sun and then passes through a heat exchanger, creating steam, which turns a turbine. The turbine generates a staggering 350 MW of electricity, making it the largest solar power system of any kind in the world.

Making use of this energy is not an easy task, but advancements are being made. In certain parts of the United States, solar energy is price competitive with fossil fuels. Consider the words of Thomas Edison when he said "I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait till oil and coal run out before we tackle that." If we can harness the massive amount of power coming from our nearest star, we just may see the Sun set on fossil fuels in our lifetime. ▲

REFERENCES

- Asimov, Isaac. *Asimov's Guide to Science*; Basic Books: NY, 1972.
- Lang, K. R. *The Cambridge Encyclopedia of the Sun*; Cambridge University Press: NY, 2001.
- Lang, K. R. *Sun, Earth, and Sky*; Springer-Verlag: NY, 1995.

Clair Wood is a freelance writer based in Veazie, ME. His most recent *ChemMatters* article "The Two Faces of Carbon" appeared in the December 2004 issue.



Alice A. Augusta Ball Young Chemist Gave Hope to Millions

By Paul Wermager and Carl Heltzel



UNIVERSITY ARCHIVES, UNIVERSITY OF HAWAII AT MANOA LIBRARIES

Imagine you are a 15-year-old returning home from school, and you are met at your front door by two officials instead of your parents. You are arrested and then told to say good-bye to your family, but hugging is not allowed. The armed officials take you to a facility for a quick physical exam. Afterward, you are sent to an isolated peninsula named Kalaupapa, bounded by vertical cliffs 2,000 feet high and surrounded by a deep ocean. Separated from your family and friends, you are banished here for the rest of your life not for what you did but for what you have: *leprosy!*

Your only escape from a lifetime sentence to this colony of exiled souls, damned by disease, rests in the hands of a young chemist named Alice Ball. She was the first to discover a chemical key that offered millions of sufferers the hope of being set free from their medical exile.

The most cursed place on earth

Jack London called it “the most cursed place on earth” and “the pit of hell” after taking a tour of the colony. Three sides of the peninsula were ringed by jagged, razor-sharp lava rock, making landings impossible. The fourth cliff rose as a two-thousand-foot wall so sheer that wild goats tumbled from its face.

For 80 years, beginning in 1866, the Hawaiian and later the American governments forcibly removed more than 8000 men, women, and children to the remote and inaccessible Kalaupapa settlement on the Hawaiian island of Molokai. The following is an excerpt from *The Colony* by John Tayman:

PAUL WERMAGER

Under a law to prevent the spread of leprosy, persons suspected of having the disease were chased down, arrested, subjected to a cursory exam, and exiled. Armed guards forced them into the cattle stalls of inter-island ships and sailed them 58 nautical miles east of Honolulu, to the brutal northern coast of Molokai. There, they were dumped on an inhospitable shelf of land of the approximate size and shape of lower Manhattan, which jutted into the Pacific from the base of the tallest sea cliffs in the world. It was, as Robert Louis Stevenson would write, “a prison fortified by nature.” In the early days of the colony, the government provided virtually no medical care, a bare subsistence of food, and only crude shelter. The patients were judged to be civilly dead, their spouses granted summary divorces, and their wills executed as if they were already in the grave. Soon thousands were in exile, and life within this lawless penitentiary



Kalawao main street (on the east side of Kalaupapa) during its early years.

NPS ARCHIVE, (WWW.NPS.GOV)

came to resemble that aboard a crowded raft in the aftermath of a shipwreck, with epic battles erupting over food, water, blankets, and women. As news of the abject misery spread, others with the disease hid in terror from the government's bounty hunters, or violently resisted exile, murdering doctors, sheriffs, and soldiers who conspired to send them away.

Some tried to escape, only to fall to their death from the cliff. Others were swept out to sea by the relentless currents.

Back on the mainland, public health and law officials rounded up thousands of people to be sent to other isolation centers across America: North Brother Island (New York City), a locked building next to San Francisco's City Pest House, Louisiana Leper Home (near New Orleans), Penikese Island in Buzzards Bay (Massachusetts), and Seattle's Diamond Point.

Leprosy

Hansen's disease (renamed after the Norwegian physician, Gerhard Hansen, who first identified the causative bacillus, *Mycobacterium leprae*) was the scourge of mankind for centuries. Its contagious, disfig-



The disfigured hands of a patient with Hansen's disease.

uring, and seemingly incurable traits terrified people across every continent. Fear and ignorance of the disease closely paralleled the early days of the AIDS epidemic. Former U.S. Surgeon General Dr. C. Everett Koop noted in a 1989 visit to Kalaupapa, "AIDS is the modern-day leprosy." The difference between them is that AIDS is caused by a virus, and leprosy is caused by a bacterium.

Leprosy is a chronic disease that affects the skin, peripheral nerves, mucus mem-

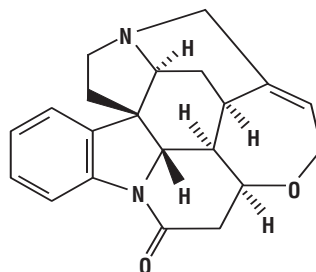
branes in the respiratory tract, and eyes. It is known to affect people of all ages from newborns to the elderly. It is most common in warm, wet areas in the tropics and subtropics.

Although the disease is known to be contagious, the exact mechanism of transmission of leprosy is unknown. It was thought that direct contact between someone with the disease and a healthy person was the only way the disease spread. Some believe that it may be spread via the respiratory route. *M. leprae* was the first bacterium that was discovered to cause disease in humans. Its size and shape resembles *tubercle bacillus*, the pathogen responsible for tuberculosis.

Though rare in the United States, the disease still surfaces in parts of Texas and Louisiana. Worldwide, there are about 600,000 new cases of leprosy reported each year.

Early treatments

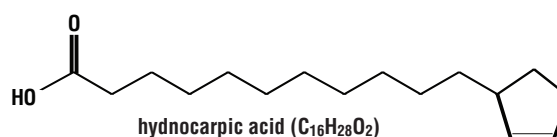
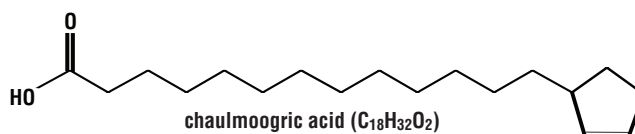
Down through the ages, desperate physicians and researchers had tried numerous treatments to combat the horrible disease, including surgery, diet, X-rays, mercury, arsenic, antimony, copper, dyes, strychnine,



strychnine

and other esoteric concoctions administered as ointments or injections. All failed to cure the disease.

Only one natural substance seemed to offer relief and improvement to some patients suffering from Hansen's disease.



Chaulmoogra oil

Since the 14th century in China and even earlier in India, chaulmoogra oil was used with moderate and inconsistent success to lessen the effects of Hansen's disease.

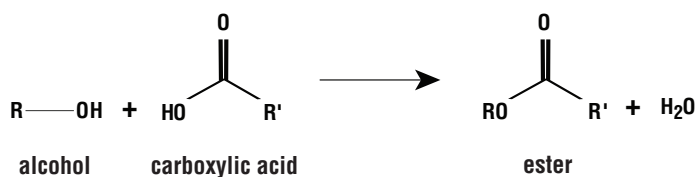
Obtained from the seeds of the chaulmoogra tree, or *Taraktogenos kurzii*, healers administered chaulmoogra oil orally or applied it as an ointment. One reason for the limited effectiveness of early chaulmoogra treatments resulted from a botanical mix-up.

Taraktogenos is from a Greek word meaning "confused" and refers to the earlier confusion between it (the true chaulmoogra) and two other genera, *Hydnocarpus* or *Gynocardia*, (both false chaulmoogras). The false chaulmoogra oil lacked several of the essential chemicals found in the true oil. Because most of the commercial chaulmoogra on the market before 1900 was false chaulmoogra, unsuspecting physicians and patients often experienced varying and disappointing results from chaulmoogra.

Chaulmoogra oil was first introduced to Hawaii in 1879 but failed to gain widespread use because of its unreliable therapeutic effects. Physicians and researchers continued to be frustrated but were also intrigued by the mystery of why some patients showed remarkable improvements with chaulmoogra oil, while others did not. Originally, the oil was applied topically to leprosy areas but external application had only limited value in treating the disease. An oral remedy was more effective but had an extremely nauseating effect on the patient. Furthermore, plain chaulmoogra had a bitter, disagreeable taste thus patients were very reluctant to take it long term.

Scientists around the world searched diligently for an effective way to administer chaulmoogra oil as an injection. Early attempts with injectable forms of chaulmoogra failed because the oily drug was virtually insoluble in water, and so it was painful when injected and created abscesses (lumps). We now know the active con-

stituents of chaulmoogra oil are chaulmoogric acid and hydnocarpic acid. These drugs are solids in their purified state and their relatively long, nonpolar hydrocarbon chains render them water insoluble.



Forming an ester from an alcohol and a carboxylic acid. R and R' represent two different hydrocarbon groups.

pharmacologists working in some of the world's most sophisticated and well-equipped laboratories had been unable to do. At the age of 24, Alice discovered the first preparation of a water-soluble, injectable form of chaulmoogra oil for the treatment of leprosy.

Her early years

Alice Ball was born on July 24, 1892, in Seattle, WA, to African-American parents. Alice grew up around chemicals. Her grandfather, J. P. Ball, Sr., was a famous photographer and one of the first African Americans in the United States to learn the art of daguerreotype (early photographic images were developed on silver-coated glass or copper plates). She probably helped out in the family photo gallery, mixing fresh developers and preparing

Enter Alice

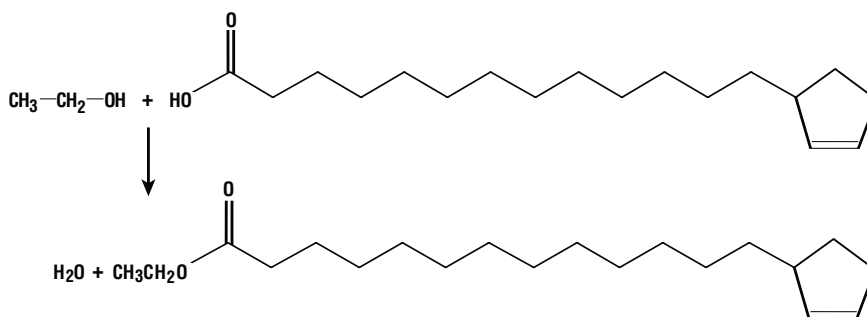
Dr. Harry T. Hollmann was the catalyst who brought the chaulmoogra problem to its chemical solution by selecting the right problem solver: Alice Ball. As Assistant Surgeon at Kalihi Hospital in Hawaii where new Hansen's disease patients were sent, Dr. Hollmann had refused to give up on chaulmoogra's promise. He'd been a physician at the federally funded Leprosy Investigation Station when it opened at Kalaupapa in 1909. In his 1922 medical article, he explained how it all began:

"I interested Miss Alice Ball, M.S., an instructress in chemistry at the College of Hawaii in the chemical problem of obtaining for me the active agents in the oil of chaulmoogra. After a great amount of experimental work, Miss Ball solved the problem for me by making the ethyl esters of the fatty acids found in the chaulmoogra oil, employing the technique herewith described."

Alice's solution to the problem involved preparing the ethyl esters of the fatty acids present in the oil. An ester can be prepared from a carboxylic acid by reacting it with an alcohol, usually in the presence of another acid as a catalyst. An alcohol has an -OH functional group, and a carboxylic acid functional group has the general formula -COOH, or -CO₂H. The ethyl ester of an acid is formed using ethanol as the alcohol.

The straight, untreated oil consists of a variety of different esters with very high molecular weights and are highly viscous. Viscosity is a measure of a substance's resistance to flow. A thick liquid like honey is highly viscous, whereas gasoline is not. Patients described the injections of chaulmoogra oil as burning like fire, and the viscous oil moved visibly through the skin like a snake slithering under a sheet. Alice's ethyl esters reduced the viscosity of the bioactive compounds in the oil. The active acids themselves are solids, and as mentioned previ-

ously, are not water soluble. When formulating a drug, water solubility is a highly desirable property for the obvious reason that, if soluble, a drug can make its way through the body (which is mostly water). Many of today's drugs are in their salt form. You can prepare the salt of a carboxylic acid by treating it with a base such as sodium hydroxide.



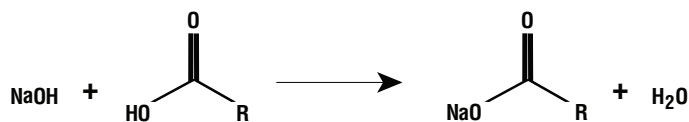
Forming the ethyl ester of chaulmoogric acid

The sodium salts of chaulmoogric and hydrocarpic acids would be water soluble. But because of their size, they would act like soaps and could cause the undesirable side effect of hemolysis (breakdown of red blood cells) when injected.

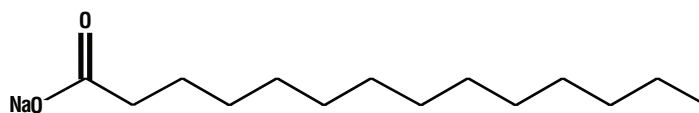
It often takes a hero to rescue us from desperate times and desperate situations. In this case, our heroine was a remarkable young female chemist. Alice Augusta Ball accomplished what many researchers, chemists, and

photographic plates. Her father, mother, and aunt were also photographers.

Alice first came to Hawaii in 1903. She accompanied her family, including her grandfather, who was suffering from arthritis and seeking comfort in Hawaii's warm climate. In 1904, her grandfather died in Honolulu, and she moved back to Seattle with her family. She attended Seattle High School and earned excellent grades, especially in the sciences. In her four years at the University of Washing-



Forming the sodium salt of a carboxylic acid.



Structure of a typical soap.

ton, Alice earned two degrees: pharmaceutical chemistry (in 1912) and pharmacy (in 1914). Before departing to Hawaii for graduate school, Alice copublished with her pharmacy instructor a 10-page article “Benzoylations in Ether Solution” in the prestigious *Journal of the American Chemical Society*.

After one year of graduate study, Alice Ball graduated on June 1, 1915, with her master’s degree in chemistry from the College of Hawaii (later renamed the University of Hawaii). Her master’s thesis involved the identification of the active constituents of kava root. She was the first woman and the first African American to graduate with a master’s degree from the college. Alice was also the first Black female instructor in the college’s chemistry department from 1915 to 1916.



Young girls during the early years at Kalaupapa.

NPS ARCHIVE (WWW.NPS.GOV)

Triumph of spirit

Reflecting on the tremendous obstacles and oppressive discrimination that Alice—and all African Americans—faced during this period of history, makes her achievements even more outstanding. Following the Civil War, the corrosive Jim Crow laws and the inhumane attitudes they engendered made life humiliating and treacherous for Blacks.

We don’t know the setbacks or disappointments that Alice experienced in her research because no record of her daily work exists. We do know that she taught chemistry classes and chemistry labs during the day so she probably conducted the chaulmoogra experiments in her free time. Because she solved the chaulmoogra puzzle rather quickly—between 1915 and early 1916—we can presume she possessed a brilliant insight and persistent work ethic.

At the height of her accomplishment, but before she could publish her research, Alice tragically became ill. She returned home to Seattle and died on the last day of December 1916, at the age of 24. The cause of her early

demise remains unknown because her death certificate was altered.

A 1917 newspaper article in the Honolulu *Pacific Commercial Advertiser* may offer a clue: “While instructing her class in September 1916, Miss Ball suffered from chlorine poisoning.” During this time, ventilation hoods were not a mandatory safety feature in laboratories.

After her untimely death, Dr. Arthur L. Dean, a chemist and President of the College of Hawaii, carried on Alice’s pioneering work. A laboratory at the College began producing large quantities of the new injectable chaulmoogra to supply the numerous requests for their preparations from all over the world.

Sadly, Alice never lived to witness the results of her discovery. In 1918, a Hawaii physician reported in the *Journal of the American Medical Association (JAMA)* that 78 patients of Kalihi Hospital were released by board of health examiners after being treated by chaulmoogra injections. During the four years between 1919 and 1923, no new patients were exiled to Kalaupapa. As late as 1936, the *Philippine Journal of Science* noted that Hansen’s disease patients treated with chaulmoogra continued to be paroled from that country’s Culion Leper Colony.

But like the ebb and flow of life, joy gave way to sadness as patients began relapsing and ships once again returned to Kalaupapa with their human cargo. It appeared that the devious bacterium had developed a resistance to Ball’s chaulmoogra. Some speculated that patients who returned to their old homes were reinfected by dormant spores in their environment. Whatever the cause, the disease began to reclaim old patients and destroy new lives, but with nothing better to offer patients, chaulmoogra remained the standard of care until the sulfones (Sulfa antibiotics) were developed in the 1940s.

The injectable form of chaulmoogra oil developed by Alice Ball gave hope to the hopeless for almost two decades that one day they would be reunited with their loved ones. Some say it also offered a new form of hope to the world. Governments and researchers don’t like to waste their time and money on hopeless causes. Ball’s chaulmoogra showed that Hansen’s disease was no longer hopeless. Increased funding for research resulted



NPS ARCHIVE (WWW.NPS.GOV)

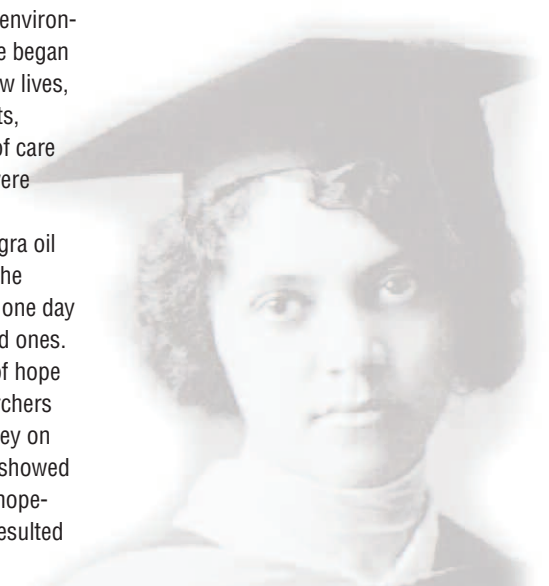
Kalaupapa National Historical Park was established in 1980. Kalaupapa is still home for many surviving Hansen’s disease patients.

in the development of the sulfones and other effective treatments for Hansen’s disease.

The Governor of Hawaii issued a proclamation on February 29, 2000, declaring it “Alice Ball Day.” On the same day, the University of Hawaii honored its first woman graduate and pioneering chemist with a bronze plaque mounted at the base of the lone chaulmoogra tree on campus. In December 2006, the Board of Regents of the University of Hawaii honored Alice’s work and memory with its Regent Medal of Distinction (posthumously conferred).

Hopefully, the world will not forget Alice Augusta Ball and how this young African-American chemist, researcher, and instructor overcame impossible odds and racial and gender discrimination to give hope to the millions of banished and forgotten victims of Hansen’s disease. ▲

Paul Wermager is a freelance writer based in Honolulu, Hawaii, and **Carl Heltzel** is the editor of *ChemMatters*.



Mentos and Diet Coke Craze

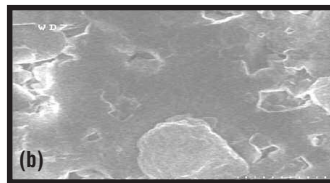
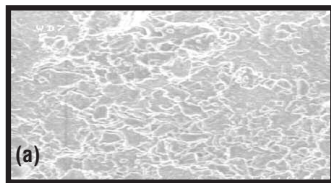
The Mentos/Diet Coke experiment has captivated the imagination of people of all ages all across the country. One group carried out the reaction with over 250 bottles of Diet Coke and 1500 mints. You can find many movies of this wacky activity at <http://eepybird.com/dcml.html>.

Going to the Sun

For a wonderful Web site that presents a wealth of information on the structure of the Sun, try heading to <http://www.columbia.edu/~ah297/unesa/sun/sun-chapter1.html>. For an activity that helps us to understand the relative sizes of the Earth and the Sun, take a look at <http://vathena.arc.nasa.gov/curric/space/sun/sunearth.html>.

More on Alice

An interesting obituary for Alice Augusta Ball, published in the Honolulu Star Bulletin can be found at <http://ftp.rootsweb.com/pub/usgenweb/hi/hawaii/obits/ball5ob.txt>. An essay on chaulmoogra oil and the treatment of leprosy, which includes the contributions made by Alice Ball, can be found at <http://lhncbc.nlm.nih.gov/lhc/docs/published/2003/pub2003048.pdf>.



Scanning electron microscope (SEM) images of the surfaces of mint (a) and fruit (b) Mentos confirm Bob Becker's surmise. The mint surface is quite rough, much more so than the fruit Mentos surface. Thanks go to Bo Gao, Gary Bernstein, and Marya Lieberman at the University of Notre Dame for the SEM images.

NASCAR

The official site from the National Association for Stock Car Auto Racing is at NASCAR.com. The site is filled with photographs, news, schedules, driving teams, and statistics.



LISA BLUMENFELD/GETTY IMAGES FOR NASCAR

Percy Julian

Another African-American chemist who made enormous contributions to the field of medicinal chemistry was Percy L. Julian. Julian made significant discoveries using soybeans that revolutionized the treatment of glaucoma and arthritis. In fact, Julian discovered ways to use soybeans for everything

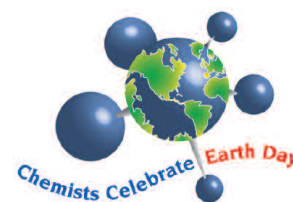
from food to fire extinguishers.

NOVA, the production company that makes films for PBS is currently producing a series of biographies of four eminent, historically significant scientists. Julian will be featured in the documentary film titled *Forgotten Genius*. The other scientists to be featured in the ACS-sponsored film series include Einstein, Galileo, and Madame Curie. For more information on Percy Julian, go to:

http://acswebcontent.acs.org/percy_julian/film.html, and http://acswebcontent.acs.org/landmarks/landmarks/pj/pj_depauw.html.

Chemists celebrate Earth Day (CCED)

The CCED theme is "Recycling—Chemistry Can!" Celebrate anytime during the week of April 22, 2007. Enter the illustrated haiku contest (all grades K–12) to win a local prize and qualify for the national contest. Start a recycling program at your school or increase awareness about the benefits of recycling. More information about CCED, the contest, American Chemical Society local contacts and local events is available at chemistry.org/earthday.



We'd like to hear from you!

Let us know about the chemistry that counts in your life.

E-mail your thoughts and suggestions to c_heltzel@acs.org, and we'll use your comments to make future issues even better. We may even print your comments in the April issue!

CHEM MATTERS

1155 Sixteenth Street, NW
Washington, DC 20036-4800

Reach Us on the Web at
chemistry.org/education/chemmatters.html