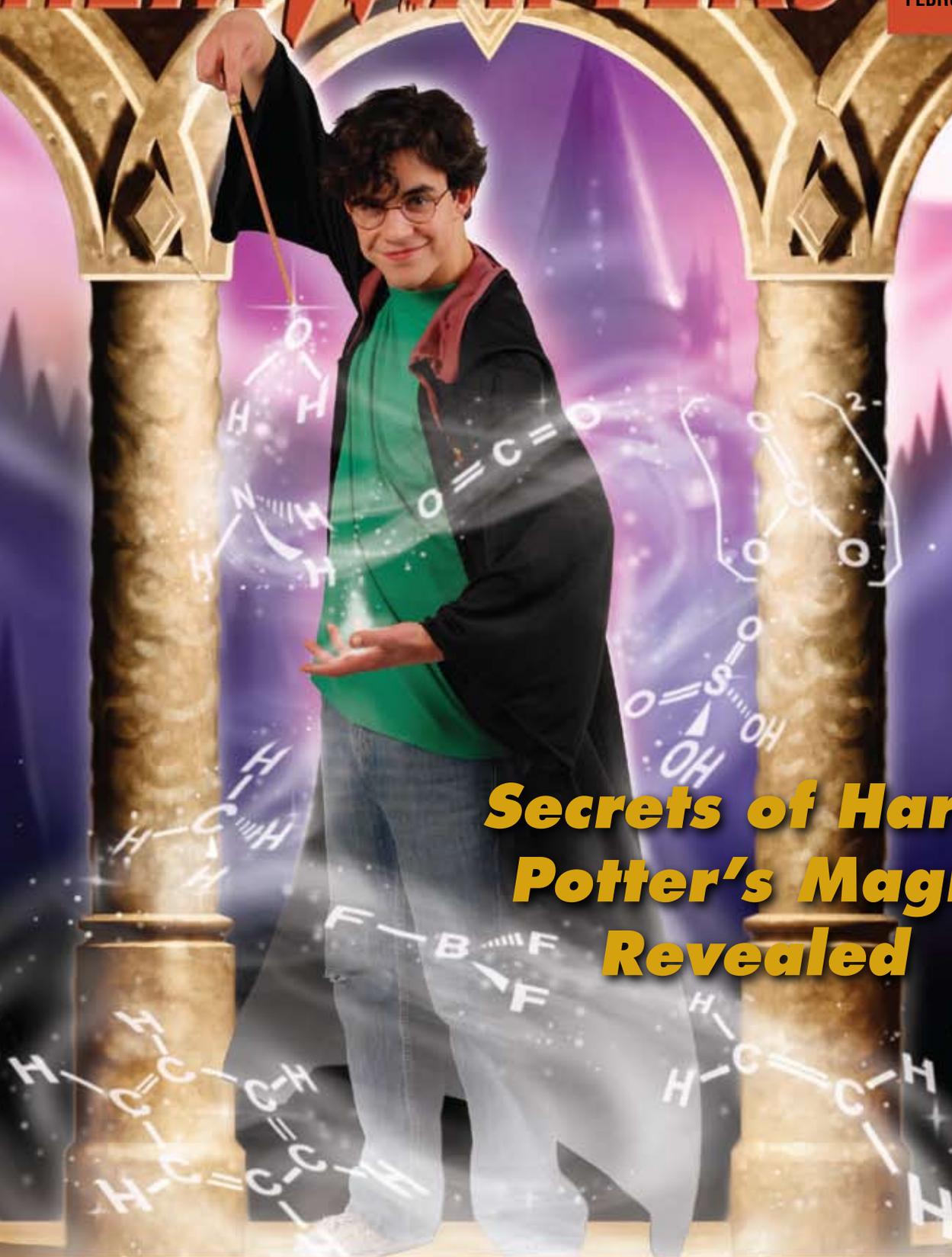


CHEM 1 MATTERS[®]



DEMISTIFYING
EVERYDAY
CHEMISTRY

FEBRUARY 2009



Secrets of Harry Potter's Magic Revealed

Bringing Chemistry to the Kitchen, p.10



QUESTION FROM THE CLASSROOM

By Bob Becker

Q. If radon is a noble gas, which means it is not supposed to react with anything, how can it be poisonous?

A. What causes certain elements to be more chemically reactive than others has to do with electrons, and more specifically, the valence electrons—those in the outermost energy level.

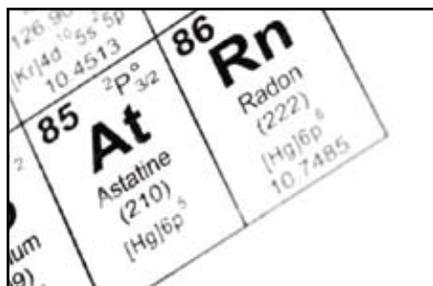
Some atoms have a strong tendency to attract extra electrons into their valence level. These “electron-hungry” atoms, called oxidizer atoms, include fluorine, chlorine, and oxygen.

Other atoms, called reducer atoms, have almost no tendency to gain electrons into their valence level. In these atoms, the valence-level electrons are weakly bound to the atom’s nucleus, so these atoms tend to lose valence-level electrons, especially when a strong oxidizer atom collides with them. Strong reducer atoms include lithium, magnesium, and sodium.

And then there are the noble gases. They are unique because they have virtually no tendency to attract any additional electrons than the ones they have. But the dangers associated with radon atoms have nothing to do with their valence electrons. Instead, they are due to these atoms’ large, unstable nuclei.

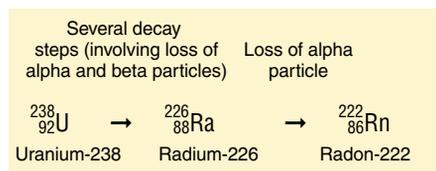
The nucleus of an atom is a region at the center of the atom that contains densely packed protons and neutrons. Protons are positively charged, so they repel one another quite strongly through electrostatic forces. But what holds the nucleus together is a force that keeps the protons and neutrons close to one another. This force, called the strong nuclear force, only exists at an extremely small scale inside the nucleus and counteracts the electrostatic forces by attracting protons to protons, neutrons to neutrons, and protons and neutrons to each other.

The number of neutrons matters too, since they stand in between the protons and prevent them from repelling each other through electrostatic forces. But once you have more than 82 protons, no number of neutrons can help make the nucleus stable. And that is the problem for radon.



With 86 protons, the nucleus of a radon atom is simply too large and unstable. So radon nuclei tend to spit out tiny two-proton-two-neutron bundles called alpha particles. This emission serves to make the nucleus more stable. But these alpha particles have enough energy to cause damage to whatever molecules they meet—such as DNA molecules in a person’s lung cells, which leads to an increased risk of lung cancer.

Radon is produced by unstable uranium atoms in uranium ore deposits deep underground. These atoms undergo radioactive decay events that spit out alpha particles and beta particles—which occur when a neutron changes into a proton—as follows:



These radioactive decays take place underground and would have no impact on our health if it weren’t for the fact that radon is a gas and therefore can be released from the soil and into the air. Not only is radon dangerous, but so are all the “daughter isotopes” that come after it in the decay series. These solid atoms can attach themselves to dust and other particulates in the air and can be breathed in as well.

Radon is in the air you are breathing right now, but at very low concentrations—too low to measure, even in parts per trillion! Radon



levels are usually measured in picocuries per liter. Typical outdoor levels are around 0.25 picocurie per liter. This means that each hour, an average of 36 radon nuclei per liter of air are decaying and giving off alpha particles. Indoors, radon levels increase to about 1 picocurie per liter. Levels are higher indoors due to the accumulation of the radon gas—especially in poorly ventilated basements.

But in some parts of the world where there are rich uranium deposits underground, the indoor levels can exceed 25 picocuries per liter; this corresponds to about 3,600 alpha emissions per liter per hour. Because one liter of air contains approximately 25 million billion molecules, 3,600 decays per hour doesn’t seem like that big a deal. But when you consider that your exposure to that radon is constant and that 3,600 decays per hour amounts to over 30 million decays per year, you may begin to appreciate the extent of your exposure! Levels as low as 4 picocuries per liter can increase a nonsmoker’s risk of developing lung cancer to 4 in 1,000 and a smoker’s risk to 30 in 1,000! ▲

Question from the Classroom

By Bob Becker

Why is radon a poisonous gas?

ON THE WEB 2

Science at Hogwarts—Chemistry in Harry Potter's World

By Jane Snell Copes

Discover the chemistry behind some of the most famous magical experiments conducted by Harry Potter and his friends in J. K. Rowling's *Harry Potter* series of books.

4

Ancient Soil Chemists of the Amazon

By Mark Michalovic

Archaeologists have discovered that a lost Amazon civilization developed intensive agriculture, thanks to a fertile soil that they call *terra preta*.

ON THE WEB 7

Bringing Chemistry to the Kitchen

By Patrice Pages

Scientists who study the chemical ingredients in food and how they interact with one another are providing new knowledge that chefs are using to make original and savory dishes.

Spanish translation available online!

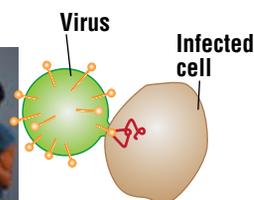
ON THE WEB 10

TEACHERS!
FIND YOUR COMPLETE TEACHER'S
GUIDE FOR THIS ISSUE AT
WWW.ACS.ORG/CHEMMATTERS

COVER PHOTOGRAPHY BY MIKE CIESIELSKI, COVER ILLUSTRATION BY ROB JOHNSON



MIKE CIESIELSKI



ANTHONY FERNANDEZ

The Art and Chemistry of Dyes

By Clair Wood

Scientists are trying to perfect the art and science of dyeing fabrics by conducting experiments in which blends of different fabrics are dyed, wool is made shrink-proof, and color remains as vivid as new.

13

Promising New Vaccines

By Barbara Boughton

Researchers are working on new vaccines that are safer, more effective, and easier to produce and that could be used against the flu, AIDS, and cancer.

16

Research Ethics 101: Interview with Margaret Cavanaugh, Chair of the American Chemical Society's Committee on Ethics

By Christen Brownlee

Chemists follow a set of ethical rules to keep the practice of science as honest as possible. But when some researchers break these rules, they hurt not only themselves, but their colleagues, the general public, and scientific research as a whole.

18

CHEM.MATTERS.LINKS

ON THE WEB 20

Production Team

Patrice Pages, *Editor*
Cornithia Harris, *Art Director*
Leona Kanaskie, *Copy Editor*

Administrative Team

Marta Gmurczyk, *Administrative Editor*
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*
Ed Escudero, *Editor*
Ronald Tempest, *Editor*
Susan Cooper, *Content Reading Consultant*
David Olney, *Puzzle Contributor*

Education Division

Mary Kirchoff, *Director*
Terri Taylor, *Assistant Director, K-12 Science*

Policy Board

Ingrid Montes, *Chair, San Juan, Puerto Rico*
Barbara Sitzman, *Tarzana, CA*
Ami LeFevre, *Skokie, IL*
Steve Long, *Rogers, AR*
Mark Meszaros, *Rochester, NY*

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/>

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 2009
American Chemical Society
Canadian GST Reg. No. 127571347
Printed in the USA

The Amazon rainforest is a wild place, seemingly untouched by human hands. Surprisingly, native people may have built a great civilization in the jungles of South America long before

Christopher Columbus crossed the Atlantic Ocean. This civilization thrived from about 2,500 years ago to about 500 years ago.

"The Amazon probably had native populations reaching over 6 million in 1491," says Clark Erickson, an anthropologist at the University of Pennsylvania. "To feed that many people, the Amazonians transformed the environment into a landscape of cultivated and tended trees interspersed with gardens, fields, and settlements."

During the past two decades, archaeologists have gathered evidence that this lost civilization developed intensive agriculture thanks to a fertile soil they called *terra preta*. The use of *terra preta* spread over thousands of square kilometers—an area as big as Virginia—and fostered the development of an advanced society.

Unlike current soil fertilization techniques, the use of *terra preta* allows the soil to remain fertile year after year. Scientists are trying to understand what makes this soil persist for hundreds if not thousands of years and are finding ways to use it to boost agricultural productivity, while reducing the use of fertilizers. Also, scientists have found that *terra preta* collects large quantities of carbon dioxide, one of the greenhouse gases contributing to global warming.

The Amazon soil problem

Scientists had previously shown that most of the Amazon's soil does not contain the nutrients that are needed to support crops. They had tried to introduce chemicals to fertilize this soil, but without sustained success. As a result, scientists had dismissed the idea that indigenous people could have survived in large numbers, assuming instead that these people probably lived in semi-nomadic groups.



RHETT BUTLER, WWW.MONGABAY.COM

Ancient Soil Chemists of the Amazon

By Mark Michalovic

So it came as a surprise when landscape archaeologist Clark Erickson discovered pottery vessels in Bolivia's Mojos Plains that seemed too big for wandering nomads. Erickson and other scientists also noticed that the area contained a network of causeways connecting villages together along with canals. Erickson now believes that this canal network was used to irrigate cultivated crops, allowing indigenous people to prosper and build villages.

"These people must have known how to grow food that modern people don't know, because farming in the Amazon is really hard to do," Erickson says. "Most Amazonian soil is orange or yellow and is made mostly of iron oxide and aluminum oxide. This soil doesn't contain many of the nutrients that plants need to survive."

The Amazonian soil is not easy to cultivate because trees in the Amazon rainforest receive their nutrients from dead plants on the forest floor, not from the soil. So when farmers chop down trees to make farmland,

the organic matter is decomposed rapidly, the carbon is transformed into carbon dioxide that goes in the air, and what is left of the organic matter is washed away by the rain. As a result, the field cannot be used for growing crops anymore. Even artificial fertilizers do not help much, because they wash away just like organic matter does.

Ions and surfaces

Unlike the Amazon soil, soil in many parts of the United States is made of silicate clays, which contain aluminum, oxygen, and silicon. Silicate clay particles trap certain nutrients on

their surfaces, keeping them in the soil. This explains why it is easier to grow crops in the United States than in the Amazon.

Plants need many different elements to survive, including potassium and calcium, which they often get from ionic compounds in the soil. Plants get potassium and calcium from ionic compounds that contain potassium ions (K^+) and calcium ions (Ca^{2+}), respectively.

Silicate clay particles have negative electrical charges on their surfaces, so they attract positively charged ions or cations. Potassium ions, calcium ions, and other cations accumulate easily onto the surfaces of silicate clay particles. So, silicate clay soils hold on to ionic compounds very tightly.

On the other hand, the surfaces of iron oxide particles and aluminum oxide par-

CHANY-CRYSTAL-ISRAEL



U.S. and Brazilian scientists examine changes in the color of *terra preta*.

JULIE GROSSMAN



A patchwork of ancient raised fields.

CLARK ERICKSON

ticles, which are present in the Amazonian soil, do not have negative electrical charges, so they cannot attract cations, which easily wash away.

Dark secrets

Instead of growing acres and acres of maize, ancient Amazonians mostly farmed by letting forest fruit and nut trees grow, while culling other types of trees. This gave them food but preserved the forest and wild-life habitat.

“Entire forests were transformed to serve humans,” Erickson says. “But maize and manioc were critical because of their use in everyday life to feast and to brew native beers for social life.”

Corn draws more nutrients from the soil than any other Amazonian crop and thus needs better soils. So, without good natural soils, the ancient Amazonians made their own.

In many places where archaeologists have found signs of ancient Amazonian towns, they have also found a very dark soil, different than the surrounding soils, which are typically yellowish white. This soil is called *terra preta*, which means “black earth” in Portuguese. “Plants grow well in this soil, and, in some cases, you can produce several times the regular yield of maize in *terra preta* as in Amazonian soil,” says soil scientist Johannes Lehmann of Cornell University, Ithaca, N.Y.

There are rich black soils in other places on Earth, but *terra preta* is different. Most black

soil is naturally rich because it contains rotting plant matter. But the black color of *terra preta* is a result of unusually high contents of biochar or charcoal. “It was mixed into the *terra preta* by human hands,” Lehmann says. “I find *terra preta* a very exciting detective story: What did the populations do to ‘make’ *terra preta*?”

Biochar is made mostly of carbon, and it helps *terra preta* hold nutrients. Lehmann found that the surface of biochar has an unusually high density of negatively charged groups of carbon and oxygen atoms called carboxylate groups. Cations would then be strongly attracted to these carboxylate groups.

Scientists are now trying to use biochar to make soil more productive. For example,



Unlike clay soil (left) and garden soil (right) found in the United States, *terra preta* allows soil to remain fertile for years.

MIKE CIESIELSKI

Georgia is known for its poor red soil, which is mostly ferric oxide. Eprida, Inc., a Georgia-based company, is now trying to use biochar-soil mixtures similar to *terra preta*. “In 110 days, we took red clay and turned it into brown topsoil, 16 centimeters deep,” says Danny Day, the founder of Eprida, Inc. “We can actually grow corn here now.” Day



Terra preta near Iranduba, Central Amazon, Brazil.

JOHANNES LEHMANN

hopes that biochar will be used to grow food in the poor soils of tropical countries, where people are often poor and food shortages are common.

Ancient soil, future fuel

Biochar is made by heating wood or other plant matter, but not by burning it. Wood consists mostly of two compounds called cellulose and lignin, which are both made of carbon, hydrogen, and oxygen. When wood burns, these compounds react with oxygen to form carbon dioxide and water, along with smoke, ash, and other gases.

But sometimes the fire doesn't get enough oxygen for combustion. Instead of burning, the cellulose and lignin break down. The hydrogen and oxygen atoms form water molecules, while the carbon atoms are left behind. The leftover carbon is biochar. This process is called pyrolysis. You may have seen biochar leftover after a campfire is extinguished. Ancient Amazonians probably made most of their biochar by heating wood in slow, smoldering, fires, specifically for mak-



Clear-cutting in the Amazon rainforest as viewed from an airplane.

PHOTO BY RHETT BUTLER, WWW.MONGABAY.COM



Clark Erickson's team, agronomy students, and local farmers studied how past farming was done by constructing their own raised fields.

CLARK ERICKSON

ing *terra preta*. "The size of most *terra preta* sites is huge, and this implies something special and intentional," Erickson says.

Day hopes to use pyrolysis to make clean fuel while making biochar. During normal pyrolysis, the hydrogen atoms and oxygen atoms in cellulose and lignin join to form water molecules. But under the right conditions, the hydrogen atoms can form hydrogen gas (H_2) instead of joining with oxygen. Day hopes to make hydrogen fuel this way.

Since the entire process of growing plants and pyrolyzing them does not produce carbon dioxide, it does not worsen global warming. But inexpensive and eco-friendly ways to make hydrogen have been difficult to find. "Hydrogen, as a form of fuel, is something that is easy to do with biomass," Day says.

When pyrolysis is carried out in just the right temperature range, it generates energy, minimizing the amount of fuel needed to produce hydrogen in the first place. Accord-

ing to Day, the pyrolysis methods can also be tweaked to make it produce biodiesel fuels, a process called hydrocarbon reforming.

Day hopes that his clean fuels and biochar soil additives will be a one-two punch in the fight against global warming. When a plant grows, it takes carbon dioxide out of the air and converts it into the materials that make up the plant—like cellulose and lignin. When the plant dies, the carbon in the plant turns back into carbon dioxide. Other times, the plant might be burned as fuel or to get rid of it. This also turns the plant's carbon back into carbon dioxide. But if you turn this carbon into biochar, that carbon does not turn back into carbon dioxide. Large-scale production of biochar for farming could cut the levels of carbon dioxide in the atmosphere, which could help reduce global warming.

Over 1,000 years ago, people in the Amazon rainforest learned how poor soil can be transformed to give good crops. They did so by using chemistry that we don't entirely understand yet. A lot of research needs to be done to figure out what they did so long ago. As we try to solve the puzzles of *terra preta*, those ancient people give us clues about the distant past while leading us to new technologies for the future. ▲

SELECTED REFERENCES

- Glaser, B.; Woods, W. I. *Amazonian Dark Earths: Explorations in Space and Time*; Springer: New York, 2004.
- Lehmann, J. Bio-energy in the Black. *Front. Ecol. Environ.*, **2007**, 5, pp 381–387.
- Mann, C. *1491: New Revelations of the Americas Before Columbus*; Vintage, 2006.
- Marris, E. Black Is the New Green. *Nature*, August 2006, 442, pp 624–626.
- Renner, R. Rethinking Biochar. *Environ. Sci. Tech.*, Sept. 1, 2007, 41, pp 5932–5933.
- Wallace, S. Last of the Amazon. *Natl. Geogr.*, January 2007, 211 (1), pp 40–71.

Mark Michalovic teaches at Bucks County Community College, Newtown, Pa. His most recent *ChemMatters* article, "Beyond Hydrogen: The New Chemistry of Fuel Cells," appeared in the December 2007 issue.

Have you ever eaten coffee while drinking biscotti? Or used a syringe while eating a salad? Or even eaten a restaurant menu? These things are now possible thanks to creative chefs who are part of a growing movement called molecular cooking, experimental cuisine, or avant-garde cooking.

The movement started in 1992 when scientists and cooks met at an international workshop held in Erice, Italy, to discuss how cooking recipes work and how they could be improved by studying the physics and chemistry behind them. The workshop was run by Nicholas Kurti, a Hungarian-born physicist who taught in Oxford, United Kingdom; Hervé This, now a professor of molecular gastronomy at the French National Institute of Agronomical Research (INRA) in Paris; and Harold McGee, an American science writer.



Hervé This (left) and Pierre Gagnaire taste one of Gagnaire's new dishes.

In these workshops, Kurti and This introduced a new field called molecular and physical gastronomy—later shortened to molecular gastronomy—to investigate the science behind cooking. The two scientists tried to understand, for example, whether adding ingredients in a recipe needs to follow a specific order. They also questioned long-held assumptions about the time it takes to cook certain meals or why temperature should be lowered or increased over the course of a meal preparation.

Over the years, Kurti and This's work generated interest from chefs, cooks, and food enthusiasts, who decided to look at cooking recipes from a new perspective too. An increasing number of chefs are now experimenting with equipment similar to that found in physics or chemistry laboratories with the goal of creating original, yet savory dishes. These dishes are now served in a few restaurants around the world, including wd-50 in New York City, Moto in Chicago, and The Fat Duck in Bray, a village located 25 miles west of London. People can also learn these new cooking techniques by attending workshops.

"There is a lot that we don't know about what happens to food as it is cooking," says

Wylie Dufresne, chef at wd-50. "But by scientifically studying the cooking process, you can learn new things that can help you combine ingredients in new ways and come up with new flavors. Also, by experimenting with food, you can make cooking more fun and you can unleash your creativity."

Molecular gastronomy

Molecular gastronomists are scientists who study what happens to food when it is cooking. They study the chemicals in food, how these chemicals change when food ingredients are mixed together, and the transformations that happen to food during cooking. Their work can be used in the kitchen to improve recipes through a better understanding of the underlying chemical composition of food.

"We want people to be able to cook creatively and not have to blindly follow recipes without knowing why

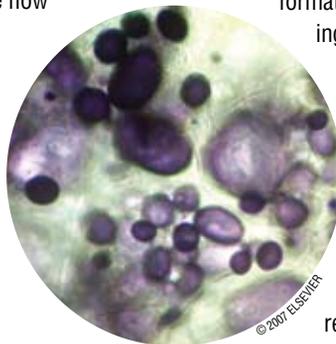


Figure 1. Potato cells observed under an optical microscope. The starch grains are stained deep purple.

you need to mix such and such ingredients in a specific order or for a specific length of time," This says.

This developed a way to describe the chemical ingredients of food using a set of symbols similar to mathematical symbols. Food is divided into different phases—liquid, gas, or solid—and the various food components have one of four dimensions: a dot, a line, a plane, or a volume.

"Food usually has the consistency of a colloid—a substance in which small particles are randomly dispersed," This says. "Potatoes, for example, consist of cells with starch granules dispersed inside them, and the cells themselves are dispersed in the solid that makes up the potato (Fig. 1). Another example is ice cream—it consists of gas bubbles, ice crystals, proteins, sucrose, and fat dispersed in water."

In his laboratory at INRA, This and colleagues conduct scientific experiments using differential equations (mathematical equations used in physics, engineering, and economics) and nuclear magnetic resonance machines (the same machines that provides

BRINGING *Chemistry* to the *Kitchen*

By Patrice Pages

images of different parts of our body). They investigate various cooking processes, including how a carrot stock is done and why the color of green beans changes during cooking.

These scientists also suggest how to apply techniques usually found in chemistry and physics laboratories to the study of nearly everything that you can buy in the supermarket: vegetables, fruit, pasta, salad dressing, mayonnaise, etc.

“We are interested in understanding how food changes in consistency, color, and structure when it is cooking, in the hope of finding processes that haven’t yet been explained by chemists, physicists, and biologists,” This says.

In 1996, This conducted an easy experiment to show that the strongest chemical forces that occur in cooking egg whites are disulfide bonds. Before he did his experiment, This was wondering how an egg white cooks.

“Raw egg white is full of tightly coiled proteins,” This says. “When you start cooking

This works closely with restaurant chefs to ensure that his research results are used in the kitchen. For the past 10 years, he has been working with Pierre Gagnaire, a well-known French chef with restaurants in many cities—including Paris, London, Dubai, Tokyo, and Hong Kong—to help him create recipes based on his latest findings.

This has proposed to create an “abstract” cuisine, in which people would not be able to recognize the food ingredients used for making a given dish. This concept is inspired from abstract art, a style invented by painters Wassily Kandinsky and Piet Mondrian that does not represent real people or things but is an arrangement of shapes and colors.

This is also encouraging other countries to create their own molecular gastronomy

of food and how the outside environment affects how people appreciate food. In other words, Barham not only combines science with the art of cooking, but he adds psychology to the mix.

Barham and colleagues at the University of Copenhagen’s Food Science Department have conducted various experiments on people eating various foods.

One of their main findings is that people associate the taste of food to memories related to these foods. For example, the researchers used the fact that changing the color of food can make people think they taste

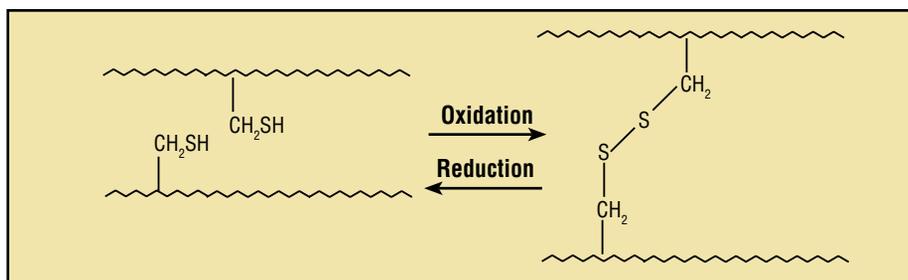
different. The scientists made jellies with red beets that were colored either orange or deep red. People who ate the orange jellies usually thought that they should taste like an orange. They didn’t recognize the beet flavor and didn’t like the jellies’ taste. But when they ate the red jellies, they recognized the taste and liked it.

Barham and colleagues are also trying to understand what makes people feel full after they eat. The scientists have shown that people may be more interested in the complex texture of food rather than its good taste.

“Some people love chocolate, cheese, or Coca Cola, so you can assume that the more of these foods you give them, the happier they will be,” Barham says. “But what we noticed is that if you give people food with an unusually good taste, they usually will savor it in their mouth longer, and end up eating less overall than if had given them, say, chocolate.” The reason this happens, Barham adds, is that people may be more interested in experiencing new tastes than tasting the same thing over and over again.



HERVE THIS



ACS STAFF

Figure 2. Egg white hardens because molecules (wiggles) inside egg white proteins bind to each other by forming disulfide (S-S) bonds (right).

egg white, some proteins in it start to unfold, and thiol groups (molecular group consisting of a hydrogen and a sulfur atom bound together) form covalent bonds between neighboring molecules inside each protein.”

These strong, stable bonds are called disulfide bridges and result from a chemical reaction in which the hydrogen atoms from each thiol group are removed and the two remaining sulfur atoms bind with each other (Fig. 2). This cross-linking between molecules inside egg white proteins causes the molecules to form networks, so the egg hardens.

So This used reducing agents to cut the disulfide bridges (reduction reaction in Fig. 2), and he noticed that the egg was “uncooked.” This experiment showed that the formation of disulfide bridges was the key process explaining the cooking of an egg.



HERVE THIS

programs. Such programs are now underway in the United States, Argentina, Cuba, and many European countries, including the United Kingdom, Italy, Spain, and Ireland. The people involved in these programs interact with each other to compare notes on their latest findings.

Psychology of food

Another molecular gastronomist is Peter Barham, a teaching fellow in physics at the University of Bristol and a professor of molecular gastronomy at the University of Copenhagen, Denmark.

But unlike This, Barham is trying to understand what makes food taste good. He is interested in how people perceive the color and tex-

Making a Spherical

Carrot Cake

One of Ben Roche's most popular desserts is the spherical carrot cake. Instead of using a large bowl, a whisk, and an oven, his tools consist of nitrogen (in both liquid and gas forms), a balloon, and a syringe.

First, Roche fills up the balloon with nitrogen gas until the balloon reaches a spherical shape. Then he uses the syringe to fill up the balloon with 60 cubic centimeters of a liquid carrot cake mix made of carrot juice, eggs, sugar, ginger, and walnuts. Then he adds a little bit of nitrogen gas to create pressure inside the balloon so that the liquid inside is forced outside the balloon.

Then Roche freezes the balloon inside liquid nitrogen. He spins the balloon around in the liquid nitrogen, causing the liquid carrot cake to freeze on the inside surface of the balloon, forming a shell. Then Roche slices the balloon with a knife, and ends up with what looks like an Easter egg. All you need to do is break it like an egg and eat it!

To make this and other desserts, Roche uses gloves and goggles. "Safety is very important when using this equipment," he says. "We don't recommend that students make this carrot cake in their kitchen. Instead, you may want to try this recipe with an experienced chef or a person trained with chemistry lab equipment."

You can watch a video of Ben Roche preparing the spherical carrot cake on the *ChemMatters* Web page: <http://www.acs.org/chemmatters>.



ACS STAFF

The dishes on the menu sound familiar, but the way they are displayed and how they taste are not. "Greek salads," for example, consist of an octopus salad—with an octopus imported from North Africa—with a salad dressing served in a syringe. You first eat the salad, and then you squeeze the syringe into your mouth, which gives you the taste of a Greek salad. (Note that these syringes are made especially for Moto restaurant, so you shouldn't use a syringe from a chemistry laboratory for that purpose!)

Other items on the menu include a "BBQ beans and slaw," which consists of a soft beef brisket cooked for 12 to 16 hours and coleslaw that melts as you eat it (because it was pureed and then frozen); a scallop filled with a liquid made from saffron (an iris-like herb) served on a tofu and vanilla puree and an orange on the side; and seared Shuteye—a broadbill swordfish from Hawaii—with tofu puree, braised seaweed, and popcorn.

The menu includes three desserts or more, depending on the type of meal that you pick. The desserts include a chocolate truffle filled with liquid Cracker Jack and popping candy, nitrogen-frozen raspberries, and a ball of white chocolate filled with a popcorn sorbet

which, when put inside the mouth, feels like popping popcorn. At the end of the meal, a waiter serves you blended biscotti in a cup and coffee that is hardened and shaped like biscotti.

The desserts are the creations of Ben Roche, Moto's pastry chef, who is as passionate about his new creations as Steve Jobs is about the new iPhone 3G. "I like to change people's expectations about food," he says. "I try to push the boundaries of baking by mixing ingredients or changing the texture of fruit. It's very rewarding when you come up with a dessert that tastes good that nobody else had tried before. But obviously, the customers are the best judges."

Interested in doing avant-garde cooking?

Most chefs who do avant-garde cooking followed a traditional cooking training. But in addition to this training, they have also learned about the science of food through books or from other chefs. They also enjoy experimenting with food ingredients to come up with dishes that taste, smell, and/or look differently than what people expect.

"We want to break the boundaries of cooking techniques by being cavalier but serious," says Daryl Nash, executive chef at Otom, Moto's "sister" restaurant in Chicago. "We look at a pie, a vegetarian dish, or a cheeseburger, and we wonder, 'How can we make it look different but taste the same?' or 'How can we make the familiar look unfamiliar or taste better?'"

One of Nash's favorite dishes on Otom's menu—which offers a mix of traditional and contemporary meals—is called a Bacon-Lettuce-and-Tomato (BLT) sandwich, except that doesn't look like a sandwich. Nash uses the same ingredients as in a BLT sandwich, but he prepares them differently. He makes a jam out of tomatoes, black pepper, and mayonnaise, creates a Romaine lettuce puree, and adds pieces of sourdough bread to the mix. "In the end, what you see is nothing like a BLT sandwich yet it tastes exactly like it," Nash says.

In some cities, such as New York and Paris, people who haven't been trained as chefs can meet with avant-garde chefs and food scientists, thanks to public outreach programs. For example, since April 2007, New York University has been organizing public meetings in which chefs, scientists, and food enthusiasts meet and talk about the latest findings in experimental cooking.

During each meeting, invited speakers make presentations on their current activities and then answer questions from the audience. The meetings are part of a program called Experimental Cuisine Collective.

If you would like to enjoy some new and unusual food, you can try to locate an avant-garde restaurant near you. You can also contact the Experimental Cuisine Collective to know more about molecular gastronomy and experimental cooking by going to their Web site: <http://www.experimentalcuisine.org/>. ▲

SELECTED REFERENCES

This, H. Food for Tomorrow? *EMBO Reports* **2006**, 7 (11), pp 1062–1066.

Jarvis, L. M. Kitchen Chemistry. *Chem. Eng. News*, July 7, 2008, pp 26–30.

Curious Cook: <http://curiouscook.com/cook/home.php>

Patrice Pages is the editor of *ChemMatters*.



MIKE CIESIELSKI



CHEM.MATTERS.LINKS

Chemistry of Harry Potter

Learn more about spectroscopy with the following resource, from the Chemistry Hypermedia Project: <http://www.chem.vt.edu/chem-ed/spec/spectros.html>. Invisible ink and pens can be found in stores and online, including at GlobRight, Inc.: <http://www.globright.com/invisibleinkpen.html>. If you want to know more about the origins of names of the chemical elements, check out the Web site of Peter van der Krogt, a researcher and teacher at the University of Utrecht in the Netherlands: <http://elements.vanderkrogt.net/index.html>.



MIKE CHESELSKI

Terra preta

The BBC, a British TV station, has produced a documentary titled "The Secret of El Dorado" on *terra preta* and the pre-historic Amazonian peoples that used it to grow crops. You can find a summary



YOUTUBE.COM

of the documentary at <http://www.bbc.co.uk/science/horizon/2002/eldorado.shtml>. An excerpt from the documentary is available on YouTube at <http://www.youtube.com/watch?v=T1eYn76b04E>.

Avant-garde cooking

Check out the following YouTube videos from three renowned chefs: Homaro Cantu, executive chef at Moto Restaurant in Chicago: <http://www.youtube.com/watch?v=47qqz4ToBfE>;



ACS STAFF

Ben Roche, pastry chef at Moto Restaurant: <http://www.youtube.com/watch?v=ykWNHXfcL20>; and Wylie Dufresne, chef at wd-50 restaurant in New York: http://www.youtube.com/watch?v=i_QtPF_MBOA

www.youtube.com/watch?v=i_QtPF_MBOA

Making and dyeing textiles

To read more about current research into how textiles are made and dyed, check out the Web sites of the College of Textiles at North Carolina State University in Raleigh: <http://www.tx.ncsu.edu/>; the Materials and Textiles Department at the University of Massachusetts at Dartmouth: <http://www.umassd.edu/engineering/mtx/research/>; and the Division of Textiles and Clothing at the University of California, Davis: <http://textiles.ucdavis.edu/>.

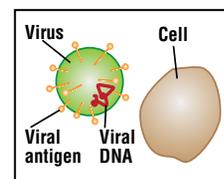
Also, you can find the latest developments on everything cotton in *Lifestyle Monitor*, the official magazine of Cotton Inc., a research and marketing company representing domestic cotton producers and importers of cotton textile products: <http://www.cottoninc.com/LifestyleMonitor/>.



MIKE CHESELSKI

Vaccines of the future

You can read more about vaccines at the Web site of the National Institutes of Health's Vaccine Research Center: <http://www.niaid.nih.gov/VRC/>. To keep up-to-date on the latest developments at the two companies described in the *ChemMatters* article—Vical, Inc. and Biological Mimetics, Inc.—check out their Web sites: <http://www.vical.com/> and <http://www.bmi-md.com/>, respectively.



ANTHONY FERNANDEZ

Science ethics

You can read more about how to incorporate ethics in the classroom and the laboratory at the National Academy of Engineering's Online Ethics Center: <http://www.onlineethics.org/>. Also, the American Chemical Society has developed ethics guidelines for chemical professionals at: <http://www.acs.org/careers> (under "Ethics & Professional Guidelines").



GETTY IMAGES



1155 Sixteenth Street, NW
Washington, DC 20036-4800

www.acs.org/chemmatters



American Chemical Society