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DEMYSTIFYING EVERYDAY CHEMISTRY

FEBRUARY 2008

The Forensics of Blood

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Demystifying Everyday Chemistry

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QUESTION FROM THE CLASSROOM, Part II

By Bob Becker

MIKE CIESIELSKI

Q. Why does shaking a can of soda make it explode all over the place when you open it? And why does tapping on the top of the can stop it from doing this?

A. As we pointed out in the last issue of *ChemMatters*, contrary to popular belief, shaking a can of soda does not increase the pressure inside the can. Shaking takes one single pocket of carbon dioxide gas at the top of the can and changes it into thousands—perhaps millions—of tiny bubbles distributed throughout the entire can. This causes a huge increase in the surface area, so there are more places for the carbon dioxide to dissolve and bubble. A typical room temperature soda can is at about three times the atmospheric pressure. When the can is opened, the pressure drops sharply, and two things happen.

First, according to Boyle's Law—which states that the volume of a gas times its pressure is constant at a fixed temperature—the drop in pressure causes each of these bubbles to increase to about three times their original volume. This makes the surface area increase to a little more than twice what it was before.

Second, the drop in pressure upsets the equilibrium. The carbon dioxide molecules inside a closed can are constantly dissolving into the soda and then bubbling back out again. According to Henry's law—which states that the amount of gas dissolved in a solution is proportional to the pressure of the gas above the solution—the dissolving rate depends on the concentration of gas carbon dioxide molecules hitting the liquid's surface and getting captured into the liquid. Likewise, the bubbling rate depends on the concentration of dissolved carbon dioxide molecules available to escape back out into the gas form.

In a closed can, these two rates are the same, and the system is said to be in a state of dynamic equilibrium. When the can is opened, however, the pressure drops, the dissolving process decreases dramatically and can no longer keep up with the bubbling process. This means that the extra dissolved carbon dioxide bubbles out.

In an unshaken can, this bubbling out happens at the liquid's surface, but it can also happen anywhere along the inside walls of the can where there is some tiny bump—also called a nucleation site—that can help bubbles to form. For this reason, bottling companies make sure that the inside walls of their cans are as smooth as possible. Otherwise, soda would spray all over the place each time a can is opened.

When a can is shaken and then opened, not only is there a great deal more surface area, but each tiny bubble can act as a nucleation site. This causes a rapid bubbling out of carbon dioxide all throughout the liquid, not just at the top. Any rapid bubbling out that occurs beneath the liquid's surface pushes the liquid above it out of the can. Voilà, you have a soda explosion.

Now why does tapping on the top of the can stop it from exploding? I had seen this technique demonstrated many years ago at a chemistry teacher's conference, and the teacher who presented it explained it this way: When the can is shaken, some of the tiny bubbles attach themselves to the inside walls of the can. As long as they stay down there, they can act as nucleation sites for rapid bubbling—as described above.

MIKE CIESIELSKI

Tapping the sides of the can jars those tiny bubbles loose; they float to the top and no longer pose a "soda explosion threat." That certainly seemed to make sense, and the demonstration confirmed it very nicely: a can of soda at room temperature was shaken vigorously for about five seconds and then opened, and soda sprayed all over the place. An identical can of soda at room temperature was then shaken equally vigorously for an equal duration, tapped about 10 times, then opened, and hardly any soda squirted out.

This seemed like a fair, well-controlled experiment. But was it? Aside from tapping vs. not tapping, the time delay between shak-

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ing and opening the can may also make a difference.

Since tapping the can does require some time, you really cannot eliminate the delay, but you can control for it. What if you simultaneously shake two identical cans—one in your right hand, one in your left—for about five seconds, then set them both down and tap just one of them for about five seconds while the other one just sits there? Then open them both the exact same way at the exact same time.


MIKE CIESIELSKI

This may sound a little tricky, but it's really not that bad, and it does control for all the factors quite nicely. Having a friend do one can while you do the other may sound easier, but that friend might shake the can a little more vigorously or open the top a little more slowly, and these would introduce additional factors that you definitely do not want.

When I tried this experiment with a variety of sodas for a variety of shaking times and delay times, I was unable to observe any consistent difference between the tapped can and the control one.

So where did this whole can-tapping idea originate? That's hard to say, but, like most superstitions and urban myths, it is something that is a lot easier to blindly accept and perpetuate than to question and truly investigate.

CORRECTION:

The caption for the top right figure of *ChemMatters*, Dec. 2007, p.7, should read: "Astronauts aboard the space shuttle have conducted experiments with candles in low Earth orbit. The flames produced were spherical and generally lasted only a minute. Why? There was plenty of oxygen available but there was no convection. The lack of convection was due to the fact that the candles appeared weightless in the shuttle. Since the shuttle is orbiting the Earth, any object inside the shuttle is subjected to both Earth's gravity and an outward, opposite force called the centrifugal force. Both forces cancel out, making any object seem weightless. In the case of the candles, CO_2 accumulated around the flame, but, with no convection to carry it away, it quickly smothered the flame. Convection only occurs in the presence of "heavy" air and "lighter" air. In the shuttle, everything is weightless."

QUESTION FROM THE CLASSROOM 2 ON THE WEB

Discover why shaking a can of soda and then opening it makes it explode all over the place. And learn whether tapping on the top of a can that has just been shaken prevents it from exploding.

The Forensics of Blood 4 ON THE WEB

By looking at the blood left behind at a crime scene, police investigators can find many clues to what happened. The investigators can use chemistry-based techniques to determine whether the victim, the criminal, and/or other people left blood at the crime scene and whether pets or other animals may have been part of the crime too.

How Chemistry Helps Make Blood Transfusion Safer 8

Although blood transfusion is common, it is not without risks. Learn about the techniques that are used to store blood, screen it against deadly diseases, and make sure it is compatible between a donor and a recipient.

Rebreathers 11

Scuba divers can stay under water for a long time, thanks to cylinders filled with air that they carry on their back. But the air scuba divers breathe out contains oxygen that can be reused by a breathing device called a rebreather.

The Not So Simple Life of Filters 14

Filters come in all shapes and sizes and perform different functions. You may be surprised to discover how many filters are present around you and may discover new filters you hadn't heard of before.

"Follow the Carbon." Follow the *What*? 16 ON THE WEB

A rover will soon join the two Mars Exploration Rovers "Spirit" and "Opportunity" that are currently exploring the red planet. Called the Mars Science Laboratory, this new rover will carry the biggest suite of instruments ever sent to the Martian surface to look for chemical evidence of past or present life there.
Spanish translation available online!

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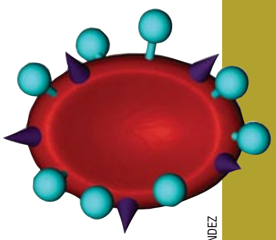
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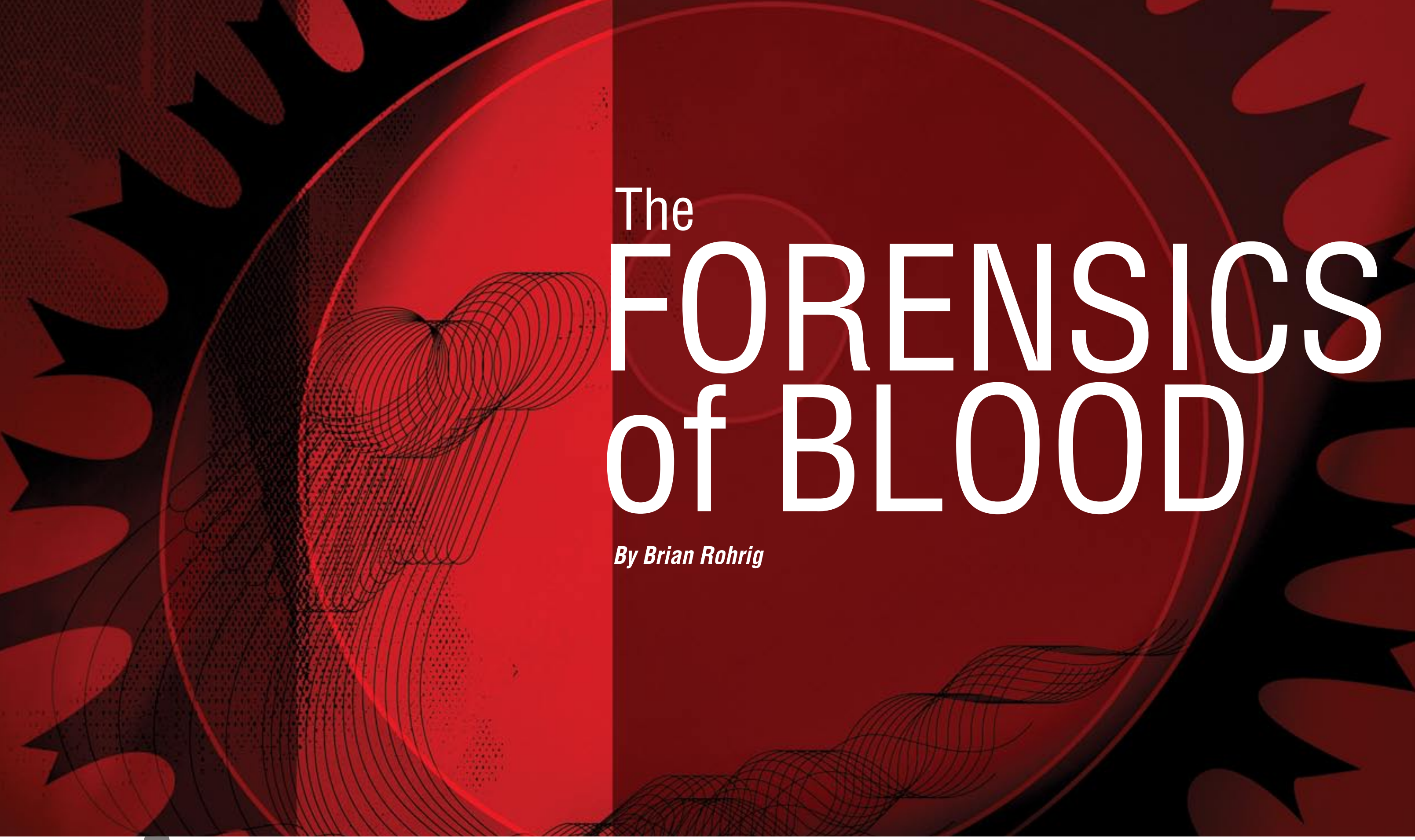

The FORENSICS of BLOOD

By Brian Rohrig

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After a homicide or an assault has been committed, police investigators usually find blood at the scene of the crime, giving them clues as to what happened. The blood's texture and shape and how it is distributed around the victim often help investigators determine when the crime was committed, whether the crime was preceded by a fight between individuals, and which weapon was used—say, a knife, a gun, or an object used to hit a person.

But criminals have tried many ways to hide, clean up, and remove blood evidence. For example, what looks like blood may be another substance placed there by the criminal to mislead police investigators. Also, some criminals clean up the blood from the crime scene or move the victim's body somewhere else, making it harder to reconstruct what really happened.

To take these potential scenarios into account, forensic scientists—who apply the latest scientific discoveries to law—have developed techniques that can tell whether the red liquid seen around the victim is actually blood, determine whether it is human blood, and establish whether the blood comes from the victim or the criminal.

Is it blood?

Until 1967, police investigators assumed that what looked like blood on a crime scene was probably blood. But a 1967 U.S. Supreme Court case called *Miller v. Pate,* in which a criminal used red paint on clothes, prompted the courts to reconsider that assumption. Several tests have since been developed to confirm that a red liquid or stain is actually blood.

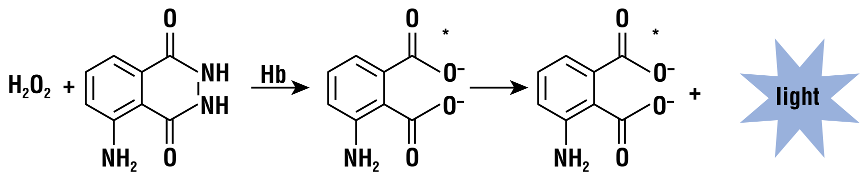
MIKE CIESIELSKI

One of these tests consists of spraying a suspected sample with a solution of luminol ($C_8H_7N_3O_2$), a chemical popularized by the TV series "CSI" (short for "Crime Scene Investigation"), and hydrogen peroxide (H_2O_2). If blood is present, the sample glows with a bluish color in the dark.

The luminol is first activated with an oxidant, usually a solution of hydrogen peroxide and a hydroxide salt in water. Then, in the presence of a protein present in blood called hemoglobin, the hydrogen peroxide is decomposed to form oxygen and water.

When luminol reacts with the hydroxide salt, a dianion is formed. The oxygen produced from the hydrogen peroxide then reacts with the luminol dianion. The product of this reaction, an organic peroxide, is very unstable and immediately decomposes with loss of nitrogen to produce 3-aminophthalic acid (3-APA) in an excited state. As 3-APA relaxes, it releases a visible blue light (see Fig. 1).

Luminol is sensitive to the presence of extremely small amounts of blood. It can detect bloodstains that have been diluted up to 300,000 times! Since it is nearly impossible to clean up every trace of blood at a crime scene, luminol is especially effective at detecting



luminol (excited 3-APA) (3-APA)

Figure 1. A chemical reaction between hydrogen peroxide (H_2O_2) and luminol (molecule pictured to the left) in the presence of hemoglobin (Hb) produces 3-aminophthalic acid (3-APA) and blue light.

minute traces of blood that may not be visible to the naked eye.

But this technique has some limitations, since the light can be produced in the presence not only of blood but also of other substances, such as copper ions, horseradish, and bleach. To positively identify a substance as blood, it is often sent to a laboratory for further analysis.

Another important test is the Kastle-Meyer test. In many crime shows on television, a blood sample is collected on a cotton swab, and then a clear solution is applied, turning the swab bright pink to confirm the presence of blood. This is most likely a demonstration of the Kastle-Meyer test.

The clear solution in this test consists of a reduced form of phenolphthalein and hydrogen peroxide, which react with each other to produce a pink solution made of water and a phenolphthalein ion (see Fig. 2). In this test, the phenolphthalein has been modified from its conventional form by being reduced and predissolved in alkaline solution, giving it a faint yellow color. Then, in the presence of hydrogen peroxide in alkaline solution, the hemoglobin in the blood catalyzes the oxidation of this form of phenolphthalein to its normal form, which generates an intense pink color.

$$H_2O_2 + OH^- + C_{20}H_{15}O_4^- \xrightarrow{Hb} 3H_2O + C_{20}H_{12}O_4^{2-}$$

Figure 2. In the presence of hemoglobin, a reduced form of phenolphthalein ($C_{20}H_{15}O_4^-$) is oxidized by hydrogen peroxide (H_2O_2) in basic solution (that is, in the presence of OH^-) to form water (H_2O) and ordinary phenolphthalein ($C_{20}H_{12}O_4^{2-}$), which is pink in basic solution.

Like the luminol test, the Kastle-Meyer test is very sensitive because it relies on a reaction catalyzed by hemoglobin, but other substances can also catalyze the reaction. Both tests are called presumptive tests—blood will cause a positive test, but so do many other substances—and they need to be substantiated by more specific tests.

Is it human blood?

Once investigators suspect that a stain is blood, they need to find out whether it is from an animal or a human being. The reason they ask such a question is that pets are sometimes present at a crime scene and can be either victims of a crime or involved in it.

To confirm whether a pet was present, investigators use various tests that differentiate between animal and human blood. One of the most widely used tests is called the precipitin test, in which the presence of human blood is revealed by making it clot.

The precipitin test is based on the fact that animals—including humans—make large quantities of proteins called antibodies that protect them against foreign, desease-causing substances. In this test, human blood is injected into a rabbit, which develops antibodies against human blood. When these "anti-human" antibodies are extracted from the rabbit's blood and added to human blood, they precipitate, forming a clot. A bloodstain from a crime scene that is added to the rabbit's anti-human antibodies will precipitate if it is of human origin.

By using the same principle, police laboratories have created other antibodies, such as "anti-dog" and "anti-cat" antibodies, that allow them to determine to which animal species a bloodstain belongs.

Whose blood is it?

A criminal investigator can determine whether the blood collected at the crime scene is from the victim, the criminal, or other people who may have been involved in the crime by identifying the blood type. There are four blood types, called A, B, AB, and O, that are defined based on which proteins are present on the surface of red blood cells.

Red blood cells contain many proteins on their surface, the most important ones being called A antigens and B antigens. Some people have one or the other, making them of type A and B, respectively. Others have both antigens, making them of type AB, while others have none of them, making them of type O.

Criminal investigators can determine blood type by adding proteins called antibodies to a blood sample. They use antibodies called anti-A and anti-B antibodies, which bind to A and B antigens, respectively. For example, if a person's blood is of type B, adding the anti-B antibodies will make the antigens bind to the antibodies, resulting in a blood clot that is easily visible. If the person is, say, of type A, nothing happens when anti-B antibodies are added to the blood sample (see Fig. 3).

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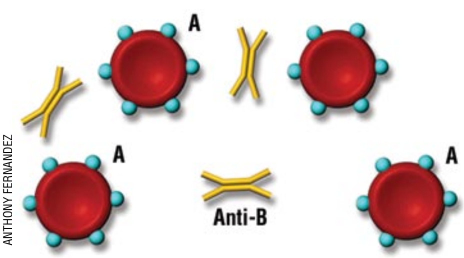


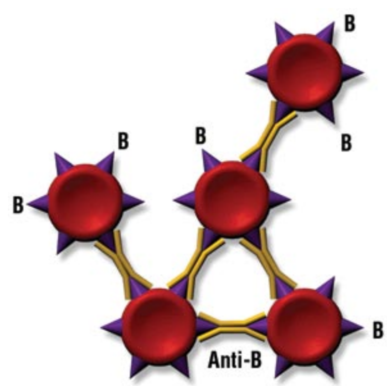


Figure 3. (Top) Red blood cells containing A antigens will not bind to anti-B antibodies. (Left) Red blood cells containing B antigens are clumped together in the presence of anti-B antibodies.

Antibodies are commercially available, so they can be used instantly to determine the type of blood present at a crime scene and from potential suspects. If the blood type of a suspect is different than the one detected at the scene, this person probably did not commit the crime. But if a suspect's blood type is the same as the one found at the scene, then this person may be the criminal. At that point, only a DNA test can confirm whether any of the remaining suspects is the actual criminal.

PHOTODISC

Bloodstains can provide important clues too

The physical properties of blood may also play a key role in allowing investigators to reconstruct events at a crime scene.

The size and shape of blood droplets can provide useful information. Blood that falls straight down will tend to form more symmetrical droplets, while blood falling at an angle will be less symmetrical (see Fig. 4).

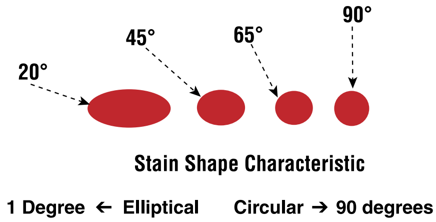
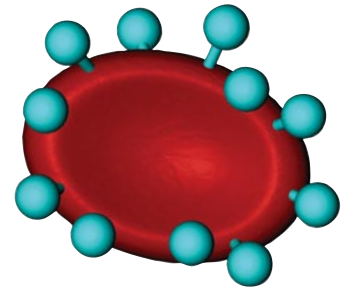
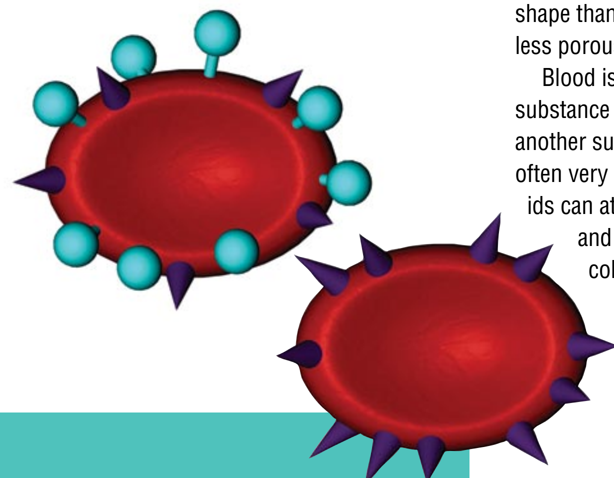


Figure 4. The shape of a blood droplet depends on the angle at which it fell.





The roughness and porosity of the surface on which blood has fallen also plays a key role—blood dropped onto concrete, for example, will tend to have a more jagged shape than blood dropped onto a softer or less porous surface.

Blood is an example of a colloid—a fluid substance where very small particles of another substance are dispersed. Colloids are often very sticky because the suspended solids can attract other chemicals. Glue, paint, and jelly are other examples of sticky colloids.

Not only is blood sticky, but it is also viscous. Viscous substances flow slowly, like molasses and honey. Since blood is both sticky and viscous, it forms readily discernible patterns on walls and other surfaces.

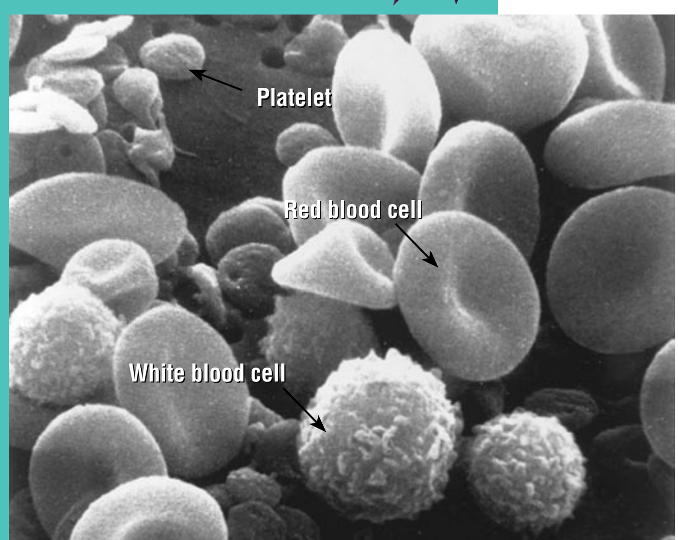
One type of pattern, called a transfer stain, results from blood that is transferred from one object to another, either when an object moves through a preexisting bloodstain onto an unstained surface—such as a foot sliding through blood—or when a blood-stained object transfers blood to another area—such as when a bloody knife is thrown down. Another type of bloodstain, called the projected stain, is produced by blood that flies off a surface under pressure.

Analyzing blood is a gruesome business, but it is necessary in order to reconstruct what happened at the scene of an accident or crime. Even in death, blood can tell a story.

ANTHONY FERNANDEZ

Blood composition

Blood contains a liquid portion called plasma, which contains mostly water along with dissolved nutrients, minerals, and oxygen. Plasma, which makes up about 55% of the blood's total volume, is a pale yellow liquid. Suspended within the plasma are two types of cells called red and white blood cells and cell fragments called platelets.



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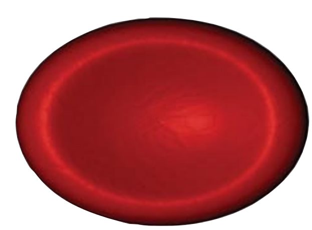
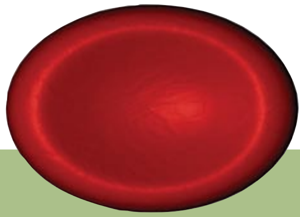
A scanning electron microscope image from human blood.

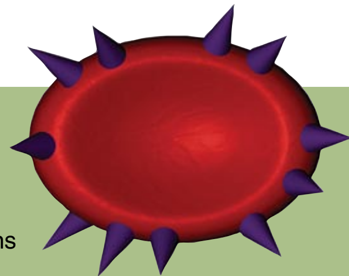
Red blood cells make up 40% of the total blood's volume, typically live for about 120 days, and are replenished at a rate of 2 to 3 million per second in the bone marrow. Red blood cells contain hemoglobin, a complex molecule that carries oxygen and removes carbon dioxide and gives blood its red color. Its molecular formula is $C_{2952}H_{4664}N_{812}O_{832}S_8Fe_4$.

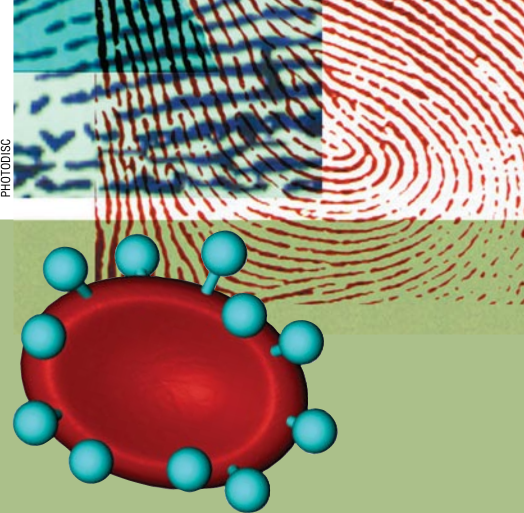
White blood cells make up 5% of blood's total volume. They are a key component of the body's immune system and play a crucial role in fighting off infection, attacking bacteria, viruses, and other microbes. The number of white blood cells present in the blood is a key indicator of health: A person suffering from leukemia has too many white blood cells, while a depressed immune system may reflect a deficiency of white blood cells.

The platelets are cell fragments involved in clotting blood, which helps stop bleeding.









PHOTODISC

Antibodies and antigens

On the surface of every cell in our body are proteins called antigens. The two main antigens present on the surface of red blood cells are called A and B antigens. Some people have only A antigens on their red blood cells, some have only B antigens, some others have both A and B antigens, and others have none, making these people's blood of type A, B, AB, and O, respectively.

Blood also contains proteins called antibodies that attach to these antigens, but antibodies attach only to foreign antigens. For example, type A blood contains antibodies called anti-B antibodies that bind only to B antigens, and type B blood contains antibodies called anti-A antibodies that bind only to A antigens. Table 1 summarizes the various antigen and antibody components of blood.

Crime scene investigators determine the blood type of a specimen by injecting either anti-A or anti-B antibodies and by seeing whether antibodies and antigens bind with one another. For example, if anti-A antibodies are used, they bind only to A antigens, so the blood type is either A or AB. By further adding anti-B antibodies to blood from the same stain would then determine whether it is of type A or AB. If it is of type A, its antigens won't bind to the anti-B antibodies; if it is of type AB, its antigens will.

Table 2 summarizes how the blood type is established (+ shows binding between the antibodies and antigens and – shows no such binding).

Determining blood type can also be done by identifying antibodies instead of antigens. A criminal investigator can use commercially available A and B cells to test for the presence of anti-A and anti-B antibodies as follows. When A cells are added to a blood specimen, the cells bind with one another only in the presence of anti-A antibodies; hence, the cells have B antigens on their surface and are of the B type. When B cells are added, the cells bind with one another when anti-B antibodies are present; hence, the cells are of the A type. All four blood types can be identified this way, as summarized in Table 3.

Blood type	Antigens	Antibodies
A	A	Anti-B
B	B	Anti-A
AB	AB	Neither anti-A nor anti-B
O	Neither A or B	Both anti-A and anti-B

Table 1. Antigens and antibodies associated with the four blood types.

Anti-A antibody + bloodstain	Anti-B antibody + bloodstain	Antigen present	Blood type
+	-	A	A
-	+	B	B
+	+	A and B	AB
-	-	Neither A nor B	O

Table 2. Identification of blood types with known antibodies.

Type A cells + bloodstain	Type B cells + bloodstain	Antibody present	Blood type
+	-	Anti-A	B
-	+	Anti-B	A
+	+	Both anti-A and anti-B	O
-	-	Neither anti-A nor anti-B	AB

Table 3. Identification of blood types with type A and type B cells.

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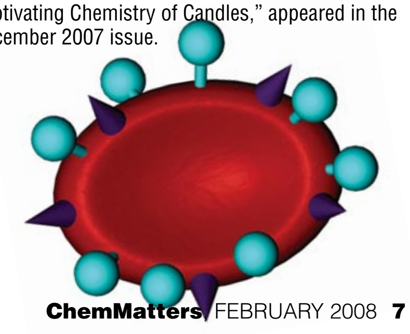
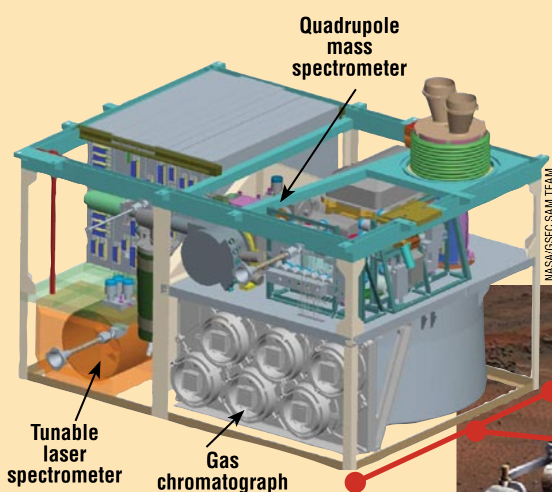


"Follow the Carbon." Follow the What?

By Lora Bleacher

"Follow the yellow brick road." "Follow the leader." You are probably familiar with both of these phrases. But who would want to "follow the carbon" and what does that even mean? To NASA, "follow the carbon" means to identify carbon-bearing compounds, their sources, and the processes that transform them in order to evaluate the habitability of Mars. And that is exactly what the Sample Analysis at Mars (SAM) suite of instruments on board the Mars Science Laboratory (MSL) intends to do.

MSL is scheduled to launch in late 2009 and will land on the surface of Mars in mid-2010, where it will spend at least one Mars year (687 Earth days) roving around the surface and collecting data. MSL will be the biggest rover yet to visit Mars. It will also carry the biggest suite of instruments ever sent to the Martian surface, including a camera, neutron detector, laser, microscope, and an analytical laboratory. SAM is one component of this laboratory.



Sample Analysis at Mars (SAM) suite of scientific instruments that will be on board the MSL rover

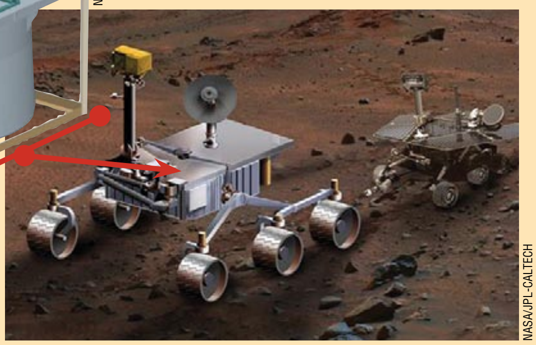


Figure 1. Illustration showing one of the two Mars Exploration Rovers (right) currently on Mars, along with the much larger Mars Science Laboratory rover (MSL) (left), which will be the largest rover ever to explore Mars.

SAM plans to "find the carbon" on Mars by collecting samples of the soil and atmosphere and analyzing them with three scientific instruments: a quadrupole mass spectrometer, a gas chromatograph, and a tunable laser spectrometer (see Fig. 1 and sidebar: **"Some Instruments Used to Study the Composition of Chemical Compounds"**). Using the results obtained by the SAM instruments, scientists back on Earth will seek to investigate the habitability of Mars by answering the question, "What do the presence or absence and characteristics of key compounds at Mars tell us about the ability of Mars to support past or present life?"

So what makes carbon so special that NASA wants to "follow it"?

In addition to liquid water and an energy source, the element carbon (C) is essential for life as we know it—that is, terrestrial life—along with other elements such as hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), phosphorus (P), calcium (Ca), and iron (Fe).

You are probably familiar with many carbon-bearing compounds, such as carbon dioxide (CO_2) and carbon monoxide (CO). When carbon is bonded to hydrogen, the resulting compound is called an organic compound.

The simplest organic compound is methane (CH_4) because it contains one carbon atom bonded to four hydrogen atoms. In addition to the carbon and hydrogen required to make a compound organic, organic compounds may also contain other elements such as oxygen, sulfur, and nitrogen. Carbon can make single, double, or triple bonds. Carbon also has the ability to bond with other carbon atoms, such that it makes long "chains" or "rings" (see Fig. 2). Because of carbon's ability to bond with many atoms in so many different ways, there are millions of organic compounds!

Every aspect of life as we know it on Earth involves organic chemistry. Your body, the food you eat, and the trees in your yard, for example, contain organic molecules. Even the smell of a rose and the hotness of a pepper are controlled by specific organic molecules.

On Earth, the simplest organic compound, methane, is primarily produced through the decomposition of biodegradable materials in wetlands and landfills and as a byproduct of digestion in humans and other animals, such as cows. The process of methane production, called methanogenesis, relies on organisms called methanogens.

Methanogens are single-celled organisms that undergo anaerobic respiration, meaning that they do not require oxygen. Although some methanogens can live in relatively mild environments, such as wetlands and the guts of humans and cows, other methanogens are extremophiles, meaning that they can survive in environments with extremely hot or cold temperatures or environments that are very saline, acidic, or alkaline.

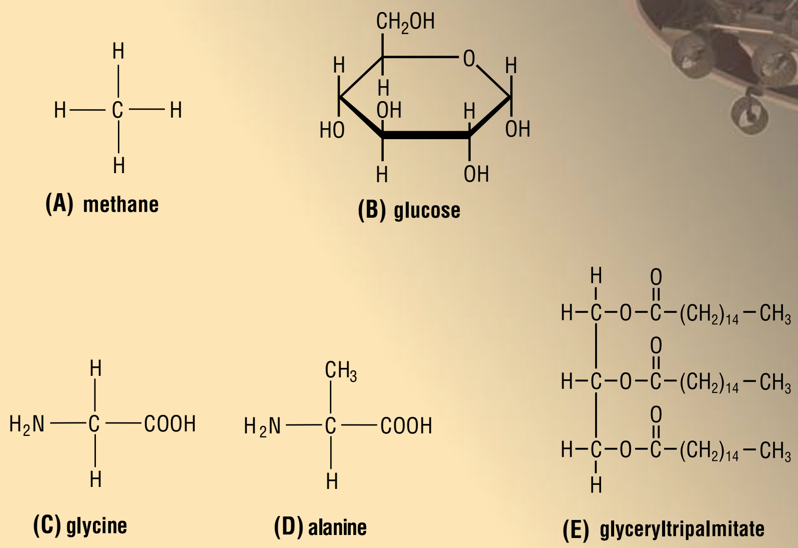


Figure 2. Examples of organic molecules: methane (A), glucose (B), glycine (C), alanine (D), and glyceryltripalmitate (E).

Two chemical reactions involved in methanogenesis are:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$
$$4CO + 2H_2O \rightarrow CH_4 + 3CO_2$$

What have we found on Mars so far?

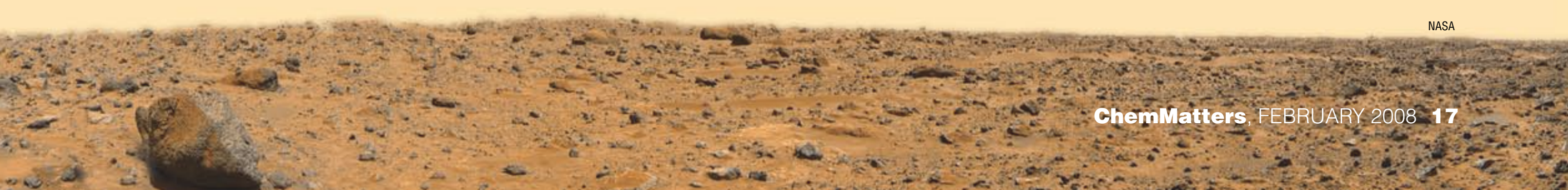
NASA has already sent landers, such as the Viking missions in 1975 and Pathfinder in 1996, and rovers, such as Sojourner in 1996 and the Mars Exploration Rovers in 2004 (which are still in operation as of the writing of this article) to Mars.

Did we detect any methane or other organic compounds on the surface of Mars with these missions? The Viking landers, which were sent to Mars specifically to look for chemical evidence of past or present life on its surface, heated soil and crushed rock samples and then used a gas chromatograph mass spectrometer (GCMS) to measure the mass of any molecules present (see Fig. 3 and sidebar **"Some Instruments Used to Study the Composition of Chemical Compounds"** for more information about a GCMS).

No methane or other organic compounds were detected. But some scientists think that the temperature to which the samples were heated in the Viking experiments (500 °C) was simply not hot enough to have revealed any

Prototype of the MSL from a test conducted in June 2007 in the "Mars Yard" of the Jet Propulsion Laboratory. The rocks are intended to simulate the shape and size of rocks on Mars that MSL might encounter.

NASA/JPL-CALTECH AND MSL ROVER TEAM



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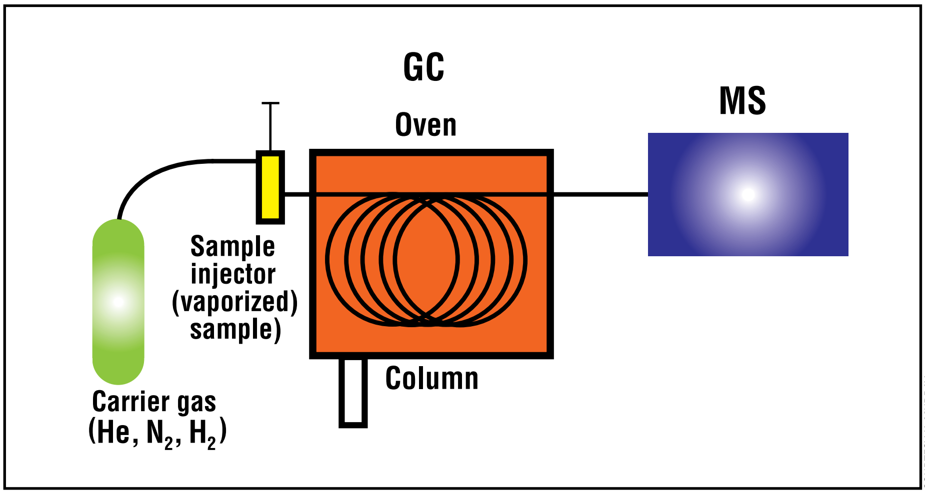


Figure 3. A gas chromatograph mass spectrometer consists of two parts: a gas chromatograph (GC), which is made of a sample injector (yellow) and a column oven (red) and a mass spectrometer (MS). After a soil or rock sample is heated to a temperature hot enough to vaporize it, the resulting gas (yellow) travels through a column within the GC. It takes longer for some molecules to travel through the column than others, so they enter the MS at different times. In the MS, the molecules are identified based on their mass.

organic compounds that may have been present, especially if they were refractory (that is, resistant to heating).

Another possibility is that organic compounds may have gone undetected because they were oxidized into carbon dioxide before being identified with the GCMS. In addition, some scientists think that organic compounds such as those that may be present on Mars may not respond to heating at all. They propose that other chemical techniques should be used when looking for organic compounds on the Martian surface.

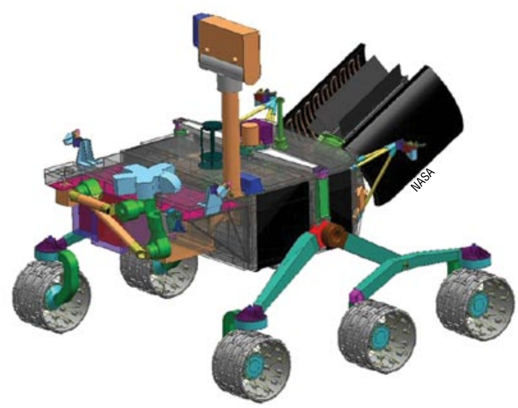
The SAM suite of instruments on the MSL will employ a GCMS and will use both of these methods. It will heat samples to higher temperatures (1000 °C) than did the Viking instruments, and it will use chemical extraction in addition to heating in order to identify any organic compounds that may be present.

Although organic compounds have not been detected at the Martian surface, a small amount of methane was detected in the Martian atmosphere by the Mars Express, a European Space Agency orbiter, in 2003. The Canada-France-Hawaii Telescope and the NASA Infrared Telescope Facility have also observed methane in the Martian atmosphere, but the source of the methane is unknown.

Could living organisms on Mars have produced the methane observed in the atmosphere and additional organic compounds at the Martian surface that are yet to be detected? Maybe. Other possibilities are that the atmospheric methane was delivered to Mars by the meteorite and comet impacts that it has experienced over and over throughout its existence, that methane has been released into the atmosphere by volcanoes, or that the methane forms as a result of a chemical reaction, involving the hydration of certain minerals found in rocks on Mars.

Will the SAM instruments be able to tell the difference between these potential sources of methane should they, in fact, find evidence of methane or other organic compounds in surface materials on Mars? Scientists may be able to distinguish the source of organic compounds on Mars by looking for patterns that are similar to those in organic compounds on Earth, in terms of their molecular structure, abundance, isotopic compositions, and geochemical contexts.

Take carbon isotopes, for example. Remember that an isotope is an atom that has a different number of neutrons in its nucleus compared to another atom of the same element. Both atoms are the same element because they have the same number of protons, but they have different masses due to different numbers of neutrons. Carbon-12 has six protons and six neutrons, carbon-13 has six protons and seven neutrons, and carbon-14 has six protons and eight neutrons (see Table 1 and Fig. 4).



SAM will measure the carbon-13/carbon-12 ratio of both methane and carbon dioxide in atmospheric samples and in the soils it collects and heats (as the samples are heated, they will release carbon dioxide and methane if present) in order to distinguish between the different sources of carbon on Mars.

Orbiter, lander, rover: What's the difference?

Orbiter: Spacecraft designed to orbit a planetary body but not to land on it.

Lander: Spacecraft designed to land on the surface of a planetary body.

Rover: Small vehicle launched from a lander that is designed to explore a planetary body.

THREE CARBON ISOTOPES				
Name	**Total Protons**	**Total Neutrons**	**Total Protons & Neutrons**	**Total Electrons**
CARBON-12	6	6	12	6
CARBON-13	6	7	13	6
CARBON-14	6	8	14	6

Table 1. Differences between three carbon isotopes: carbon-12, carbon-13, and carbon-14.

Organic compounds made by organisms on Earth favor carbon-12 over carbon-13 in a process called isotopic fractionation. During this process, heavy and light isotopes partition differently between two compounds. This happens because the bond energy of each isotope is slightly different, with heavier isotopes having stronger bonds and slower reaction rates.

Because light isotopes form weaker chemical bonds in a compound than heavy isotopes, it requires less energy to form bonds between carbon-12 atoms than it does between carbon-13 atoms and carbon-12 atoms in a compound. Organic compounds on Mars may exhibit a similar fractionation trend if produced by past or present organisms.

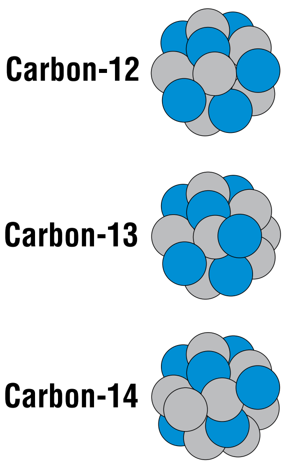


Figure 4. Nuclei of three carbon isotopes, containing (from top to bottom) six, seven, and eight neutrons (gray) and six protons each (blue).

Scientists may also be able to use a carbon isotope pattern to distinguish any organic compounds it finds as being from Mars instead of from meteorite impacts. This is because the most common type of meteorite to fall on Earth, and presumably Mars, called chondrites, has been found to contain "abiotic" organic compounds, that is, the organic compounds were not made by biological organisms. The carbon in this meteoritic material is enriched in the isotope carbon-13 relative to carbon-12.

However, some abiotic physical processes can also fractionate isotopes. Thus, the SAM scientists must take into account multiple lines of evidence—such as the environmental context from which samples are taken and analyzed—when evaluating the habitability of Mars.

Did life ever exist on Mars? Stay tuned …

The SAM suite of instruments will be used to explore the conditions necessary for life on Mars as it rides aboard the largest, most technologically advanced rover ever sent to the red planet! SAM will "find the carbon" on Mars using its comprehensive suite of three scientific instruments that will work together, along with other instruments on board the rover, to investigate the habitability of Mars.

Follow the engineers and scientists behind SAM and the MSL mission at **http://ael.gsfc.nasa.gov/marsIndex.shtml and http://mars.jpl.nasa.gov/msl/**.

Some Instruments Used To Study the Composition of Chemical Compounds

Spectrometer: Measures the interaction between light and a material and analyzes the light absorbed, emitted, or scattered by this material to determine its chemical composition.

Mass spectrometer: Breaks a sample apart by vaporizing and ionizing its constituents, and then separates these ions according to their mass and charge, which helps determine the chemical composition of the sample.

Laser spectrometer: Determines the chemical composition of a material by measuring how this material interacts with light from a laser.

Quadrupole mass spectrometer: Uses oscillating electrical fields to separate the ions according to their mass and charge.

Gas chromatograph: Separates the components of a sample by vaporizing it into a stream of gas and passing the gas through a column whose walls are covered with a polymer; the different components of the sample stick differently to the polymer, which helps separate them and later identify them based on their respective affinities for the polymer.

Gas chromatograph-mass spectrometer: A combination of a gas chromatograph and a mass spectrometer: separates the components of a sample by vaporizing it into a stream of gas and passing the gas through a column, and then analyzes these components with a mass spectrometer.

REFERENCES

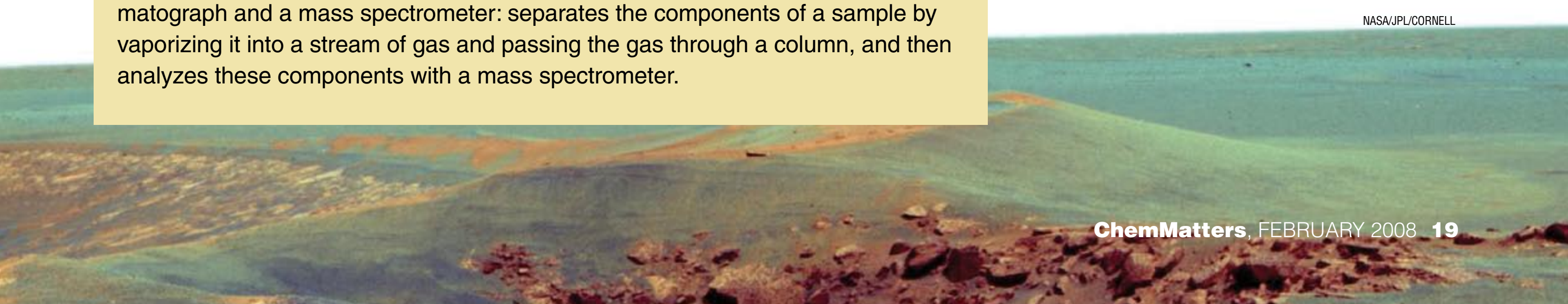
Mars Science Laboratory:
http://mars.jpl.nasa.gov/msl/

Mars Science Laboratory's instruments:
http://mars.jpl.nasa.gov/msl/mission/sc_instruments.html

Past, present, and future missions to Mars:
http://mars.jpl.nasa.gov/missions/index.html

Lora Bleacher works for Science Systems and Applications, Inc., as an outreach coordinator. This is her first article for *ChemMatters* magazine.

NASA/JPL/CORNELL



CHEM.MATTERS.LINKS

Forensics of blood

If you are curious about how forensic scientists work or if you want to become a forensic scientist, you may want to check out the Web site of the American Academy of Forensic Sciences: **http://aafs.org/.** Look, in particular, for information in the sections "Resources" and "Employment" on the top menu.

You can also buy a blood forensic chemistry kit from *OnlineScienceMall*, a Web site that sells chemistry kits: **http://www.onlinesciencemall.com/Shop/Control/Product/fp/vpid/2746761/vpcsid/0/SFV/30852**. The kit contains four simulated blood samples and the chemicals you need to find out the types of these blood samples.

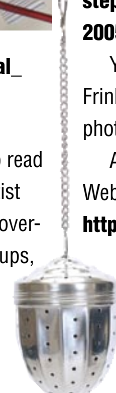
Blood transfusion

The Nobel Foundation, which awards every year the Nobel Prizes in Physics, Chemistry, Physiology or Medicine, Literature, and Peace, has prepared a nicely written and well-illustrated Web site on blood transfusion:

JUPITER IMAGES

http://nobelprize.org/educational_games/medicine/landsteiner/readmore.html.

On this Web site, you can also read about Karl Landsteiner, the scientist who won the Nobel Prize for discovering the A, B, AB, and O blood groups, and you may have fun playing a "blood-typing game"!



Filters

Filters used in chemistry, photography, electronics, and computers are described *Wikipedia*, the online encyclopedia written by Internet users: **http://en.wikipedia.org/wiki/Filter**.

You can find daily news and events about a large variety of filters at **http://www.filtsep.com/**.

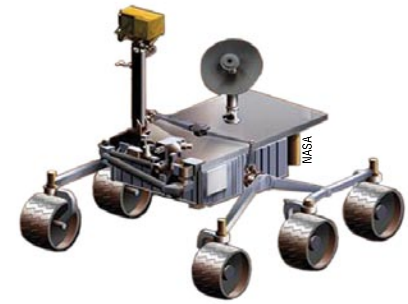
Rebreathers

Stephen Frink, the world's most widely published underwater photographer, shares his experience using a rebreather and the photos he took while using one at **http://www.stephenfrink.com/sf-tips/200506-uw-photo-rebreather/**.

You can also check out Stephen Frink's Web site for many amazing photos: **http://www.stephenfrink.com/**.

An informative and well-illustrated Web site on rebreathers is available at **http://www.therebreathersite.nl/**.

GEORGE J. FISCH, THE SCUBA CONNECTION



NASA

More on the Mars Science Laboratory and Mars exploration

The Mars Science Laboratory (MSL) is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of Mars. More information on this program can be found at **http://mars.jpl.nasa.gov/overview/**.

If you and/or your school want to be involved in the Mars Exploration Program, check out **http://mars.jpl.nasa.gov/classroom/students.html**.

In every issue of *ChemMatters*, one of the articles is now translated in Spanish! Available online at www.acs.org/chemmatters.

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