

**April/May 2017 Teacher's Guide**

**for**

***Growing Green on the Red Planet***

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# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

# Student Questions

**Growing Green on the Red Planet**

* 1. What does Mark Watney need in order to survive on Mars until NASA sends a rescue mission?
	2. What type of scientist is Mark Watney?
	3. Name three places on Earth that have been used to study Mars.
	4. According to this article, why is Mars much colder than Earth?
	5. Why is it necessary to regulate the use of manure as fertilizer on Earth?
	6. Describe the chemical reaction that is involved in photosynthesis.
	7. Nitrogen, phosphorus and potassium are primary nutrients for plants. What is the purpose of each of these nutrients?
	8. Describe the difference between macronutrients and micronutrients.
	9. How does the gravity on Mars compare to that on Earth?
	10. List the three factors cited in the article that would make it difficult to grow plants on Mars.
	11. What are the sources of oxygen and hydrogen that Mark Watney used to make water on Mars?

# Answers to Student Questions

**(taken from the article)**

**Growing Green on the Red Planet**

* + 1. **What does Mark Watney need in order to survive on Mars until NASA sends a rescue mission?**

*Mark Watney will need food and water to survive on Mars.*

* + 1. **What type of scientist is Mark Watney?**

*Mark Watney is a botanist.*

* + 1. **Name three places on Earth that have been used to study Mars.**

*The three places on Earth used to study Mars are:*

1. *Antarctica*
2. *Hawaii*
3. *South America*
	* 1. **According to this article, why is Mars much colder than Earth?**

*Mars is much colder that Earth mainly because it is farther away from the sun than is Earth.*

* + 1. **Why is it necessary to regulate the use of manure as fertilizer on Earth?**

*It is necessary for U.S. environmental agencies to regulate the use of manure to prevent the spread of viruses and bacteria that could contaminate the crops.*

* + 1. **Describe the chemical reaction that is involved in photosynthesis.**

*Water and carbon dioxide react to produce oxygen and sugars in photosynthesis.*

*6 H2O + 6 CO2 🡪 6 O2 + C6H12O6*

* + 1. **Nitrogen, phosphorus and potassium are primary nutrients for plants. What is the purpose of each of these nutrients?**

*Nitrogen is an important element in chlorophyll, which is needed for photosynthesis.*

*Phosphorus is a component in the chemical reactions that involve photosynthesis.*

*Potassium is involved in the opening and closing of the pores in leaves and stems, which allows the uptake of carbon dioxide and water.*

* + 1. **Describe the difference between macronutrients and micronutrients.**

*Macronutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, are needed in large quantities for plant life. Micronutrients, which include iron, manganese, zinc, copper, boron, molybdenum, and chlorine, are important for plant growth but are only need in small quantities.*

* + 1. **How does the gravity on Mars compare to that on Earth?**

*The gravity on Mars is 38% that of Earth’s.*

* + 1. **List the three factors cited in the article that would make it difficult to grow plants on Mars.**

*Factors that would make it difficult to grow plants on Mars include:*

1. *extreme cold temperatures*
2. *sunlight hitting Mars is much less that what Earth gets*
3. *Mars’s atmosphere is not as thick as Earth’s*
	* 1. **What are the sources of oxygen and hydrogen that Mark Watney used to make water on Mars?**

*Mark Watney obtained the oxygen from the oxygenator, which produced oxygen from the atmospheric carbon dioxide. He produced hydrogen by dissociating hydrazine, N2H4, which was the propellant for the rocket.*

# Anticipation Guide

Anticipation guides help to engage students by activating prior knowledge and stimulating students’ interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions: *Before reading***, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Research shows that Martian soil cannot be used to grow plants.
 |
|  |  | 1. Next to Earth, Mars appears to be the most habitable planet in our solar system.
 |
|  |  | 1. The atmosphere of Mars is about 50% carbon dioxide.
 |
|  |  | 1. All of the macronutrients required for plant life are nonmetals.
 |
|  |  | 1. Micronutrients are usually supplied to plants through fertilizers.
 |
|  |  | 1. Organic waste (manure) is very good for fertilizing soil.
 |
|  |  | 1. The chemistry in Weir’s book *The Martian* is plausible.
 |
|  |  | 1. Volcanic soil in Hawaii is similar to Martian soil.
 |
|  |  | 1. Watering plants on Mars could require less water than on the Earth.
 |
|  |  | 1. Hydrazine is a rocket propellant containing only nitrogen and hydrogen.
 |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Students’ understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies:***

* Links to **Common Core Standards for Reading**:
	+ ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
	+ ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
	+ ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
	+ ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
	+ ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
	+ ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
* **Vocabulary** and **concepts** that are reinforced in this issue:
	+ Chemical reactions
	+ Macro- and micronutrients
	+ Personal and community health
	+ Proteins
	+ Structural formulas
	+ Biochemistry
	+ Consumer choices
	+ Recycling
* Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them in their personal lives.
* Consider asking students to read “Open for Discussion” on page 4 to extend the information in “Growing Green on the Red Planet” on pages 5-7.
* The infographic on page 19 provides more information to support the article “Espresso, Café Latte, Cappuccino…A Complex Brew” on pages 10-12.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.
* The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

**Directions**: As you read, complete the graphic organizer below to describe the chemistry of growing plants on Mars.

|  |  |  |
| --- | --- | --- |
|  | **What chemicals are needed?** | **How can they be obtained on Mars?** |
| **Atmosphere** |  |  |
| **Soil** |  |  |
| **Water** |  |  |

**Summary:** On the bottom or back of this paper, write a short email (about 3 sentences) to a friend who wants to know whether the chemistry in *The Martian* is a good indicator of how future scientists can grow food on Mars.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Descriptive chemistry**—This article could be used to discuss the characteristics and importance of several elements, especially those important to plant growth.
2. **Limiting reagent**—The discussion of macronutrients and micronutrients can be used as an example of a limiting reagent.
3. **Energy conversion**—This article serves as an example of the conversion of light energy from the sun to chemical energy in the plants.
4. **Light energy, wavelength and activation energy**—As you discuss the relationship between light energy and wavelength you can use the information in this Teacher’s Guide to cite the pigments in plants and their colors as an example of how absorbed light determines the color of the pigment. You could also relate the light energy absorbed by plants as the activation energy in the photosynthesis process.
5. **Synthesis and decomposition reactions**—The decomposition of hydrazine to produce hydrogen, and then the synthesis of water from the hydrogen provides real life practical examples of these reaction types.
6. **Oxidation-reduction reactions**—The production of oxygen from carbon dioxide, the decomposition of hydrazine to form nitrogen and oxygen, the synthesis of water from hydrogen and oxygen, and photosynthesis are all excellent examples of redox reactions mentioned in the article
7. **Greenhouse effect**—While studying the greenhouse effect, you could discuss how the thin Martian atmosphere affects the daily and seasonal temperatures on Mars.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“The dust storms on Mars have strong, destructive winds like in the movie, *The Martian*.”** *Dust storms do exist and can last for long periods of time on Mars. The atmosphere on Mars is only 1% of that on Earth. Since the atmosphere is so thin, even a strong wind would have little force, since the force is a function of velocity and atmospheric density. In the strongest storm you would feel a breeze but it wouldn’t be able to knock a person over. The wind would be strong enough to fly a kite, but not much else.*
2. **“The Martian atmosphere is thinner than Earth’s, so it should allow much more sunlight to penetrate to the surface of the planet to make it warmer.”** *That might be true during the daytime when the sun’s rays hit the planet, but the thin atmosphere of Mars also does not hold in nearly as much of the sun’s energy at night as Earth’s atmosphere does.*
3. **“With an atmosphere of 95% carbon dioxide, plants should really flourish on Mars.”** *Unfortunately, even though its atmosphere is 95% carbon dioxide, the atmosphere on Mars is only about 1% as concentrated as the atmosphere on Earth. That means there won’t be enough carbon dioxide on Mars to sustain plants outdoors (never mind the cold temperatures), unless we concentrate the atmosphere in some way.*
4. **“Organic fertilizers are better.”** *The plant doesn’t care where the nutrients come from. Organic fertilizers do release their nutrients to the soil more slowly, since they are bound in complicated organic compounds and require microbial activity to release them. The concentration of nutrients in organic fertilizer is generally lower, requiring the use of more fertilizer. Organic fertilizers do improve the soil by adding organic material. There are certainly advantages and disadvantages to using organic fertilizers.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“Is it safe to use human feces as fertilizer?”** *The use of untreated human feces as fertilizer can be risky, since it can carry disease-causing pathogens. When human waste is treated by the municipal treatment plant it is then referred to as “biosolids”. It is treated to ensure that there are no pathogens or other hazardous materials. Once treated and tested the biosolids are safe to use as fertilizers for crops.*
2. **“Don’t manures stink?”** *Treated manures (biosolids) do have their own distinctive odor, depending on the treatment process. Some have a slight musty ammonia odor, while others have a much stronger odor that people would not find pleasant. The odor is primarily caused by compounds containing sulfur and ammonia which are nutrients for plant.*
3. **“Is it really possible to send a manned mission to Mars?”** *NASA has a goal to have a manned mission to Mars by 2030. They believe it will take international cooperation and private industry support.*

*“We are farther down the path to sending humans to Mars than at any point in NASA's history," Bolden [NASA administrator and astronaut] said during an event at NASA Headquarters in Washington, D.C. that detailed NASA's manned Mars plans.*

*"We have a lot of work to do to get humans to Mars, but we'll get there," Bolden said.*

*Some of this work includes developing a capsule called Orion and the Space Launch System (SLS) megarocket to help get astronauts to deep-space destinations. Orion and the SLS are scheduled to fly together for the first time, on an unmanned test flight, in 2018, with a manned flight to take place in 2021.*

*Newman [NASA deputy administrator] cited the fact that astronauts recently grew (and ate) lettuce on the International Space Station, as part of an experiment designed to better understand the production of food crops away from Earth.*

*Furthermore, two crewmembers on the orbiting lab — NASA astronaut Scott Kelly and cosmonaut Mikhail Kornienko — are halfway through an unprecedented yearlong mission that is characterizing the psychological and physiological effects of long-duration spaceflight. Such work should inform planning for crewed Red Planet missions, which could take astronauts away from Earth for 500 days or more, NASA officials have said.*

*Newman also mentioned the*[*Mars Oxygen ISRU Experiment*](http://www.space.com/26705-nasa-2020-rover-mars-colony-tech.html)*(MOXIE), one of seven science instruments that NASA's next Mars rover will carry toward the Red Planet when it blasts off in 2020.*

*MOXIE will pull carbon dioxide from the thin Martian atmosphere and turn it into pure oxygen and carbon monoxide, demonstrating technology that could keep settlers alive on the Red Planet — and help them blast off the surface when it's time to go home. (Oxygen can be used as an oxidizer, helping to burn rocket fuel.)*

*.*

*"We're going to make oxygen on another planet — the first time ever to make oxygen on another planet," Newman said. "These experiments — they're real, they're here."*

*Such work is being done in service of an epic and monumental goal.*

*(*[*http://www.space.com/30580-nasa-manned-mars-mission-reality.html*](http://www.space.com/30580-nasa-manned-mars-mission-reality.html)*)*

*As of a news release on February 24, 2017, NASA is actually completing a feasibility study of putting two astronauts aboard the Space Launch System (SLS) for its initial flight in late 2018. A new report on this new study can be found at:* [*http://www.cbsnews.com/news/nasa-studies-adding-crew-to-super-rocket-test-flight/*](http://www.cbsnews.com/news/nasa-studies-adding-crew-to-super-rocket-test-flight/)*.*

# Activities

**Labs and demos**

1. **A lab to determine the contents of a fertilizer:** The “Fertilizer Components” laboratory activity is a basic qualitative analysis lab that tests for nitrates, phosphates, sulfates, ammonium ions, iron(III) ions, and potassium ions. This lab procedure can be found in the textbook *Chemistry in the Community*. (American Chemical Society *Chemistry in the Community*, 6th ed., W. H. Freeman and Company/BFW: New York, 2012; pp 507–512)
It can also be found online at <https://books.google.com/books?id=wYtpGEbAB1cC&pg=PA412&lpg=PA412&dq=Chemistry+in+the+Community+Fertilizer+Components&source=bl&ots=eb3_69Imss&sig=6l6wTpWF-uGxq3fS2piVxL4IM4U&hl=en&sa=X&ved=0ahUKEwiLmOvUhJ_SAhXFbiYKHQe-Az8Q6AEIGjAA#v=onepage&q=Chemistry%20in%20the%20Community%20Fertilizer%20Components&f=false>.
2. **A laboratory activity to analyze phosphates in fertilizer:** “Analysis of Phosphorus in Plant Food” quantitatively determines the amount of phosphorus in a fertilizer. This lab would be good for an advanced chemistry class, for the students are to determine the calculations they will need to perform in order to determine the mass percent of P2O5 in the fertilizer. (<https://www.emich.edu/chemistry/genchemlab/documents/10-phosphorus.pdf>)
3. **A simple student lab for the electrolysis of water:** “Electrolysis of Water Experiment” uses common household materials. This is written for a sixth grade class but could easily be adapted for high school students. (<https://www.education.com/science-fair/article/water-electrolysis/>)
A similar version of the lab that is geared for high school students can be found on the American Association of Chemistry Teachers Web site for those who are members: <https://teachchemistry.org/classroom-resources/electrolysis-of-water>.
4. **A demonstration for the electrolysis of water:** “Electrolysis of Water” provides teacher instructions for demonstrating the electrolysis of water using the Hoffman apparatus, as well as an alternative procedure using a Petri dish. A reference to a video for both procedures is also included. (<https://projects.ncsu.edu/project/chemistrydemos/Electrochem/Electrolysis%20of%20Water.pdf>)

**Simulations**

1. **Simulation of the rate of photosynthesis:** “Measuring the Rate of Photosynthesis of Elodea” provides an opportunity for students to collect data on the rate of photosynthesis versus the amount of light. (<https://www.reading.ac.uk/virtualexperiments/ves/preloader-photosynthesis-full.html>)
2. **Simulation of photosynthesis:** “Illuminating Photosynthesis” is a series of simulations produced by NOVA. The first simulation, “The Cycle” shows the process of photosynthesis at the macroscale; sunlight striking the plant, watering the plant and the plant producing oxygen. The second simulation, “Atomic Shuffle”, illustrates photosynthesis on the molecular level. (<http://www.pbs.org/wgbh/nova/nature/photosynthesis.html>)
3. **Greenhouse Effect simulation:** This PhET simulation, “The Greenhouse Effect”, allows students to explore the relationship between various greenhouse gases, their concentrations, photons and temperature. There are many teacher submitted activities associated with this simulation. (<https://phet.colorado.edu/en/simulation/greenhouse>)
4. **Simulation of the electrolysis of water:** The “SEPUP Electrolysis Simulation” demonstrates the process at the molecular level. It provides an explanation of the processes occurring at the anode and the cathode. The animation may be stopped and started as needed. (<http://www.sepuplhs.org/high/hydrogen/electrolysis_sim.html>)

**Media**

 **Videos**

1. **Mars:** “Magnificent Mars: 10 Years of Mars Reconnaissance Orbiter” is a short video (2:20) produced by NASA Jet Propulsion Laboratory. It shows spectacular pictures taken from the Mars Reconnaissance Orbiter. (<https://www.youtube.com/watch?v=bdHkgtLgcSY>)
2. **The color of Mars:** “Is Mars Really Red?” is a short animated video (1:00) produced by NASA that explains the red color of Mars. (<http://mars.nasa.gov/multimedia/videos/?v=29>)
3. **Explanation of the use of manure:** “Treated Human Waste as Fertilizer” is a video (7:43) that investigates the use of human waste as fertilizer. The video shows the process of treating and testing the human waste from Los Angeles. The process turns the human waste into biosolids, which are then applied to fields to grow crops. (<https://www.youtube.com/watch?v=9HPCW5020SU>)
4. **Photosynthesis:** This Khan video, “Photosynthesis” (13:37), provides an overview of the process of photosynthesis. There are other Khan videos that go into more detail that can be found at the same site: <https://www.khanacademy.org/science/biology/photosynthesis-in-plants/introduction-to-stages-of-photosynthesis/v/photosynthesis>.
5. **Photosynthesis using graphics:** “Photosynthesis: Crash Course Biology #8” is a video (13:14) that provides an explanation of photosynthesis. The presenter is energetic and his explanation is interspersed with excellent graphics that demonstrate the photosynthesis process. (<https://www.youtube.com/watch?v=sQK3Yr4Sc_k>)
6. **Reaction of hydrogen and oxygen:** This video, “Hydrogen and Oxygen Gas Reaction” (2:57), provides an explanation of the reaction to produce water. It shows the explosive nature of the reaction. (<https://www.youtube.com/watch?v=RudCaJB_Xx4>)

**Lessons and lesson plans**

1. **Series of lessons on soil science:** *From the Ground Up: The Science of Soil*, produced by Discovery Education, is a series of six lessons dealing with soil, plants, and the chemistry associated with them. Each lesson provides objectives, teacher background, detailed instructions and a PowerPoint presentation. The titles of the lessons are: “In Search of Essential Nutrients”, “Properties of Soil”, “Plant Soil Interactions”, “Plant Soil Deficiencies”, “Fertilizers and the Environment”, and “Nourishing the Planet in the 21st Century”. (<http://www.thescienceofsoil.com/teacher-resources>)
2. **Series of activities dealing with the chemistry of fertilizers:** *The Chemistry of Fertilizers* is a series of activities designed for high school chemistry classes. It provides an overview of the unit, objectives, time requirements, and materials needed for each lesson. Additional resources are also provided. (<http://archives.lessoncorner.com/e4defd9f8135458f3.pdf>)

**Projects and extension activities**

1. **A research project dealing with NASA’s technologies:** Students could be assigned to research and report about the technologies that NASA is developing and compare them to those in the movie *The Martian*. Some of the technologies the students could research and compare to the movie might include: developing the habitat, growing plants in space, recovering water, generating oxygen and creating land rovers, to name a few. An article that could be used to initiate the research can be found at <https://www.nasa.gov/feature/nine-real-nasa-technologies-in-the-martian>.
2. **Scientific analysis of a science fiction movie:** Students could be assigned to watch a science fiction movie to identify the science presented in the movie. They would then research and report on the validity and feasibility of the science presented in the movie. Some movies that could be used for this include *2001: A Space Odyssey*, *Apollo 13*, *The Right Stuff, Andromeda Strain,* and the *Star Wars* movies.
3. **A home experiment to compare fertilizers:** At home, students could perform an experiment to determine whether inorganic or organic fertilizers are most effective for growing plants. A description of such a project can be found at <https://www.education.com/science-fair/article/plant-grow-chemical-organic-no-fertilizer/>.
4. **Debate on the use of fertilizers:** The use of various types of fertilizers can be controversial. Students could spend time researching the pros and cons of various types of fertilizers. The debate could center over whether organic (manure) or inorganic (synthetic) fertilizers are better.

# References

**(non-Web-based information sources)**

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen).**

**Selected articles and the complete set of
Teacher’s Guides for all issues from the past three
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**

***30* Years of *ChemMatters !***

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The article “Life on Mars” describes the purpose and the experiments performed by the Viking 1 and Viking 2 spacecraft that landed on Mars in 1976. One of the purposes of the landers was to determine if there was life on Mars. The experiments describe the theory behind them, what they detected and the analysis of the results. (Scott, D. Life on Mars. *ChemMatters*, 1994, *12* (4), pp 10–13)

The exploration of Mars by the Pathfinder spacecraft and its robotic rover, Sojourner, are described in this article. The soil of Mars was examined, and it was determined that it has many similarities to the soil on Earth. The article explains the methods used to analyze the Martian soil and rocks. (Stone, C. Clues from a Far Planet. *ChemMatters*, 1998, *16* (2), pp 7–9.)

This article describes the purpose of the Mars Science Laboratory that was sent to Mars in 2010. The purpose of this mission was to search for carbon. In the article, the various methods to detect carbon are explained. (Bleacher, L. Follow the Carbon. Follow the What? *ChemMatters*, 2008, *26* (1) pp 16–19.)

The importance of nitrogen in fertilizer is described in this article. It includes a good explanation of the nitrogen cycle. The use of manure and some advantages of organic farming are described. The hazards of excess nitrogen in the environment is also explored. (Nolte, B. Nitrogen From Fertilizers: Too Much of a Good Thing. *ChemMatters*, *28* (2), pp 5–7.)

The Teacher’s Guide for the April 2010 ChemMatters fertilizer article above provides more information on nitrogen, its compounds and its pollution. It also contains the sources for a nitrogen cycle activity as well as a simulation on the nitrogen cycle.

# Web Sites for Additional Information

**(Web-based information sources)**

**Mars**

 This NASA site has a graphic comparison of Mars and Earth. (<http://mars.nasa.gov/allaboutmars/facts/#infographic>)

 This is a short article produced by *National Geographic* and NASA about Mars, its water and its landscape. In addition, there are nice graphics of Mars, its moons and its relationship to our solar system. (<http://science.nationalgeographic.com/science/space/solar-system/mars-article/>)

 At this site you will find a more detailed article about Mars. It includes information about the size, orbit, composition, moons, atmosphere and climate of Mars. There are also several imbedded videos in the article dealing with Mars. (<http://www.universetoday.com/14701/mars/>)

 Another extensive article about Mars, it composition, atmosphere, and climate can be found at <http://www.space.com/47-mars-the-red-planet-fourth-planet-from-the-sun.html>.

**Plant growth and nutrients**

The basic needs of plants are briefly discussed at this site: <http://www.aces.uiuc.edu/vista/html_pubs/hydro/require.html>.

 This is an extensive article about the nutrient requirements for plants. It provides information on the role each nutrient plays. (<http://www.ncagr.gov/agronomi/pdffiles/essnutr.pdf>)

 More information about plant nutrients can be found at this site. The information at this site is a little more concise and given in a bulleted format. (<http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm>)

 This article provides a comparison between inorganic and organic fertilizer. It provides the comparison in a chart, as well as providing a discussion on the history, cost, and supply of nutrients. (<http://www.diffen.com/difference/Chemical_Fertilizer_vs_Organic_Fertilizer>)

 At this site, a graphic comparison of organic and inorganic fertilizers can be found. (<http://www.majordifferences.com/2013/10/difference-between-organic-manures-and.html#.WK3oNzsrJPZ>)

**Photosynthesis**

A basic explanation of photosynthesis is given at this site. It includes a discussion of the cellular components essential for photosynthesis, as well as the photosynthetic process. (<http://www.livescience.com/51720-photosynthesis.html>)

 This article on photosynthesis includes illustrations that help in the understanding of the process. (<http://www.nature.com/scitable/topicpage/photosynthetic-cells-14025371>)

 A study guide on photosynthesis for students can be found at this site. It provides a review of the processes involved, study questions, and a photosynthesis quiz. (<http://chemistry.about.com/od/lecturenotesl3/a/photosynthesis.htm>)

 The Khan tutorial on the introduction of photosynthesis can be found at this site. The explanation of photosynthesis includes graphics to aid in student understanding. More tutorials on the specific processes involved in photosynthesis can be accessed from this site as well. (<https://www.khanacademy.org/science/biology/photosynthesis-in-plants/introduction-to-stages-of-photosynthesis/a/intro-to-photosynthesis>)

**Oxygen generation in space**

This short NASA article discusses the Mars Oxygen ISRU Experiment (MOXIE), which will be on the Mars Rover in 2020 and will make oxygen from carbon dioxide. It includes a schematic of how it will work. (<http://mars.nasa.gov/mars2020/mission/instruments/moxie/for-scientists/>)

 This article explains the scientific process that MOXIE will use to generate oxygen on Mars. (<http://ssed.gsfc.nasa.gov/IPM/PDF/1134.pdf>)

 A technical paper on the production of oxygen using solid oxide electrolysis is found at this site. It explains the process as well as the experimentation that has occurred to test the process. (<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.6749&rep=rep1&type=pdf>)

 At this site, the production of oxygen on the International Space Station is discussed and explained. (<http://science.howstuffworks.com/oxygen-made-aboard-spacecraft.htm>)

**Hydrazine**

At this site, information on hydrazine, as well as sources for the information, can be found: <https://pubchem.ncbi.nlm.nih.gov/compound/hydrazine#section=Synonyms>.

 A discussion of the hydrazine and its uses can be found at <https://eic.rsc.org/magnificent-molecules/hydrazine/2000023.article>.

 This article on hydrazine provides a little information on how it is produced and some of its uses. The uses described include: as a reducing agent, as a precursor for organic synthesis and blowing agents, and as a rocket thruster fuel. (<http://www.chm.bris.ac.uk/motm/hydrazine/hydrazineh.htm>)