“Chemistry Rocks!”

(October/November 2017 Issue)
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## Connections to Chemistry Concepts

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<tr>
<th>Chemistry Concept</th>
<th>Connection to Chemistry Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties of matter</td>
<td>The physical and chemical properties that are used to identify different minerals are an example of how these properties are used in geology.</td>
</tr>
<tr>
<td>States of matter</td>
<td>Igneous rocks begin in the liquid state and solidify upon cooling. The rate of cooling will affect the crystals that form and their size. This can be used to connect to the different states of matter.</td>
</tr>
<tr>
<td>Chemical bonding</td>
<td>The discussion of metallic and covalent bonding in mineral crystals can be used to supplement a unit on chemical bonding.</td>
</tr>
<tr>
<td>Crystal lattice formation</td>
<td>The shape of the different mineral crystals provides an opportunity to discuss crystal lattices and lattice energy.</td>
</tr>
<tr>
<td>Elements and compounds</td>
<td>Minerals are composed of compounds which are the source for the extraction of individual elements. Many elements were discovered through the analysis of minerals. This connection can be made while discussing elements and compounds.</td>
</tr>
<tr>
<td>Mixtures</td>
<td>Most rocks are solid mixtures of several minerals. These can be used as examples in classifying matter as pure substances or mixtures. Some rocks may fall under pure substances while most others would be classified as mixtures.</td>
</tr>
<tr>
<td>Chemical nomenclature</td>
<td>Many of the minerals have the familiar ionic formulas students write when learning about chemical nomenclature. These formulas can be used to demonstrate that many of the chemical names they are accustomed to have common mineral names as well.</td>
</tr>
<tr>
<td>Chemical formulas</td>
<td>The many chemical formulas used throughout this article could be used during lessons concerning the writing and meaning of chemical formulas.</td>
</tr>
</tbody>
</table>
Teaching Strategies and Tools

Standards

- 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.

- In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:
  
  **ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.
  
  **ELA-Literacy.WHST.11-12.1A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

- Links to Next Generation Science Standards:
  
  **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
  
  **Disciplinary Core Ideas:**
  
  - PS1.A: Structure and properties of matter
  - PS2.B: Types of Interactions
"A Toxic Dose of Water: How Much is Too Much?" ChemMatters, October/November 2017 Issue

- **Crosscutting Concepts:**
  - Patterns
  - Structure and function
- **Science and Engineering Practices:**
  - Developing and using models
  - Planning and carrying out investigations
- **Nature of Science:**
  - Science addresses questions about the natural and material world

### Vocabulary

**Vocabulary** and **concepts** that are reinforced in October 2017 issue:

- Equilibrium
- Solute and solvent
- Electrolyte
- Ions
- Lipids
- Osmosis
- Metallic and nonmetallic
- Igneous, sedimentary, metamorphic rocks
- Composting
- Aerobic and anaerobic
- Carcinogen
- Heavy metals
- Amalgam
- Polymerization
- Composites
Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

- **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student 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.

- **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student 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 article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Excellent</td>
<td>Complete; details provided; demonstrates deep understanding.</td>
</tr>
<tr>
<td>3</td>
<td>Good</td>
<td>Complete; few details provided; demonstrates some understanding.</td>
</tr>
<tr>
<td>2</td>
<td>Fair</td>
<td>Incomplete; few details provided; some misconceptions evident.</td>
</tr>
<tr>
<td>1</td>
<td>Poor</td>
<td>Very incomplete; no details provided; many misconceptions evident.</td>
</tr>
<tr>
<td>0</td>
<td>Not acceptable</td>
<td>So incomplete that no judgment can be made about student understanding</td>
</tr>
</tbody>
</table>

- **Student Reading Comprehension Questions (p.9-10):** The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.

- This article supports the 2017 National Chemistry Week theme of “Chemistry Rocks!”
• 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. The “Web Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

• 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. Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.
# Anticipation Guide

**Directions:** *Before reading the article*, 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.

<table>
<thead>
<tr>
<th>Me</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Statement</strong></td>
</tr>
<tr>
<td></td>
<td>1. All known minerals are chemical compounds.</td>
</tr>
<tr>
<td></td>
<td>2. Most rocks are mixtures of several minerals.</td>
</tr>
<tr>
<td></td>
<td>3. Large crystals form quickly.</td>
</tr>
<tr>
<td></td>
<td>4. All crystals are held together by metallic bonds.</td>
</tr>
<tr>
<td></td>
<td>5. Halide minerals contain elements such as chlorine and fluorine from the halogen group on the Periodic Table.</td>
</tr>
<tr>
<td></td>
<td>6. Rubies and sapphires are composed of the same mineral.</td>
</tr>
<tr>
<td></td>
<td>7. Your fingernail has a hardness greater than talc.</td>
</tr>
<tr>
<td></td>
<td>8. Minerals always leave a streak on unglazed porcelain that is the same color as the mineral.</td>
</tr>
<tr>
<td></td>
<td>9. Sedimentary rocks are the most common rocks on Earth’s surface.</td>
</tr>
<tr>
<td></td>
<td>10. Limestone and marble are both composed mainly of calcium carbonate, $\text{CaCO}_3$.</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>---</td>
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</tr>
<tr>
<td><strong>New things you learned about rocks and minerals</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Ways a knowledge of chemistry can help you understand rock formation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Question you have about rocks or minerals</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Contact!</strong></td>
<td>How can an understanding of the chemistry of rocks and minerals affect your life?</td>
</tr>
</tbody>
</table>
Directions: Use the article to answer the questions below.

1. How are rocks defined?

2. Give two examples of rocks composed of only one mineral.

3. How does the arrangement of atoms differ in crystals and glass?

4. What determines the type of bonding in a crystal?

5. Describe the type of bonding present in diamonds and the effect of this bonding.

6. Name five (5) properties used to identify minerals.
Student Reading Comprehension Questions, cont.

7. Fluorescence can be used to identify some minerals. When a mineral fluoresces, what is happening?

8. How does a streak test help distinguish two minerals with similar appearance?

9. Name the three types of rocks, and give an example of each type.

10. How is the formation of granite different from that of pumice?

11. How are metamorphic rocks formed?

12. Give an example of a metamorphic rock and the rock from which it originated.
Answers to Student Reading Comprehension Questions

1. **How are rocks defined?**
   A rock is defined as a mineral—“a naturally occurring inorganic solid with a definite chemical composition and ordered internal structure—or a mixture of several types of minerals.”

2. **Give two examples of rocks composed of only one mineral.**
   Examples of two rocks that are composed of one mineral are pyrite and quartz.

3. **How does the arrangement of atoms differ in crystals and glass?**
   The arrangement of atoms in crystals is a regular repeating pattern; while in glass, the atoms have no orderly arrangement (it is amorphous).

4. **What determines the types of bonding in a crystal?**
   The types of bonds that exist in a crystal depend on the types of elements from which it is composed.

5. **Describe the type of bonding present in diamonds and the effect of this bonding.**
   Diamonds have many covalent bonds between the non-metallic carbon atoms; these involve the sharing of an electron pair between atoms. These bonds make diamond the world’s hardest mineral.

6. **Name five (5) properties used to identify minerals.**
   The five properties that are used to identify minerals are:
   a. luster,
   b. color,
   c. hardness,
   d. streaking, and
   e. fluorescence.

7. **Fluorescence can be used to identify some minerals. When a mineral fluoresces, what is happening?**
   When a mineral fluoresces, it absorbs ultraviolet light and emits visible light.

8. **How does a streak test help distinguish two minerals with similar appearance?**
   A streak test can be used to distinguish two minerals with similar appearance when the marks they make when rubbed across a piece of unglazed porcelain are different colors. For example, the streak color for fool’s gold is black, while that for actual gold is yellow.

9. **Name the three types of rocks, and give an example of each type.**
   The three types of rocks are:
   a. igneous rocks, example: pumice or granite;
   b. sedimentary rocks, example: sandstone, coal, or limestone; and
   c. metamorphic rocks, example: marble or slate.

10. **How is the formation of granite different from that of pumice?**
    The formation of granite is different from that of pumice in that granite forms underground as magma cools slowly. Pumice forms quickly when the magma is rapidly ejected into the atmosphere. Once in the atmosphere, gases escape from the rock creating a porous structure, making pumice one of the few rocks that floats.
11. **How are metamorphic rocks formed?**
   Metamorphic rocks are formed when igneous or sedimentary rocks are subjected to high temperature and pressure deep underground, causing a change in the rock. The metamorphic rock is typically harder and stronger than the rock from which it originated.

12. **Give an example of a metamorphic rock and the rock from which it originated.**
   Slate is an example of a metamorphic rock, it begins as shale and is changed into slate. Marble is another example of a metamorphic rock. It begins as limestone and is changed into marble.
Possible Student Misconceptions

1. “All rocks contain minerals.” This is almost, but not quite, correct. Rocks are defined as consolidated material composed of one or more minerals. However, obsidian which is volcanic glass, is one of the few rocks that is not composed of minerals. Glass is an amorphous solid without a defined chemical composition or structure. Minerals, on the other hand, are crystalline solids that have a definite chemical composition and structure.

2. “Diamonds are made from coal.” This misconception is still taught in many science classrooms. Two observations can be used to support the idea that diamonds are not metamorphosed from coal. Coal is a product of the metamorphosis of ancient land plants. Diamonds that have been dated are much older than the Earth’s first land plants so this seems to disprove that diamonds could be formed from the high pressure and heat treatment of coal. A second observation is that coal seams occur as horizontal or nearly horizontal layers of rock while diamonds are found in vertical pipes of igneous rocks. Therefore, it seems that diamonds formed in another way. Geologists believe diamond deposits were formed in the mantle and brought to the surface through volcanic activity. The high pressure and temperature that are required for diamond formation occurs only in some places in the mantle 90 miles below Earth’s surface. Coal veins are generally no more than 2 miles from the surface. The carbon source for diamonds is most likely carbon that was trapped in Earth’s interior during formation. A second way diamonds can be formed is during the subduction of one plate under another during plate tectonic processes. A third way diamonds are formed is when an asteroid impacts the Earth. Small diamonds have been discovered near asteroid impact sites. More information about diamond formation can be found here: http://geology.com/articles/diamonds-from-coal/.
### Anticipating Student Questions

1. **“Why are the minerals with transition metals so colorful?”** The factor that separates transition metals from the other elements on the periodic table is the filling of the d orbitals in this group of elements. In the absence of d orbitals, or when all the d orbitals become filled (e.g., zinc), colorful compounds are not observed because the energy changes that take place in these elements as they bond with others falls outside the energy associated with visible light, and the only color that is seen is white. When transition elements bond with ligands in mineral formation, the electrons in the d orbitals are used. As d orbitals become bonding orbitals, energy is absorbed as some change to lower-energy positions and some to higher-energy positions. This energy change generally occurs in the wavelengths associated with the energy of the visible light spectrum, resulting in a colored compound. For example, if the energy that was absorbed by the promotion of the d orbital to a bonding orbital falls in the yellow frequency, then the color we see is the color opposite yellow on the color wheel—blue. A more thorough explanation using Crystal Field Theory can be found here: [https://chemistry.stackexchange.com/questions/4667/why-do-transition-elements-make-colored-compounds](https://chemistry.stackexchange.com/questions/4667/why-do-transition-elements-make-colored-compounds).

2. **“Why are diamonds the hardest rocks?”** Diamonds are incredibly hard because of the structure their carbon atoms assume while forming under extreme conditions of heat and pressure 140 to 150 kilometers beneath the earth’s surface. The bonding network in diamonds is responsible for their hardness. Diamonds are composed of carbon atoms that are covalently bonded to four other carbon atoms, forming a tetrahedron. The strength and quantity of these covalent bonds give diamonds their hardness.

3. **“What minerals are in the precious stones like emeralds, rubies, and sapphires that are used in jewelry?”** Emeralds are gem quality specimens of the mineral beryl, Be₃Al₂(SiO₃)₆. Trace amounts of chromium or vanadium in the mineral cause it to develop a green color. Rubies and sapphires are both made of the mineral corundum, Al₂O₃. Chromium impurities give rubies their characteristic red color, while trace amounts of iron and titanium give the corundum the characteristic blue color of sapphires. Purple amethysts are a variety of quartz, SiO₂. The purple color is due to trace amounts of iron that has been irradiated. Opals are hydrous silicon dioxide, SiO₂·nH₂O. The silicon dioxide in opals is amorphous—without a definite crystalline arrangement.

4. **“What gives the gemstones their specific colors?”** Gemstones are made from basic minerals that by themselves are not very colorful. The trace amounts of some of the transition metal elements that are incorporated into the crystalline structure of the stone give the gemstones their specific colors. Trace amounts of chromium or vanadium make emeralds green. Chromium impurities make rubies red, trace amounts of iron and titanium make sapphires blue, while irradiated iron is responsible for the purple color of amethysts.

5. **“What type of rocks are formed from the lava that slowly oozes out of a volcano?”** When lava slowly oozes from a volcano, igneous rocks are formed. The structure of these rocks is different from the igneous rocks that form underground, though they may have the same chemical composition. Rocks that harden at the surface have smaller and finer crystals, looking more homogeneous in appearance. Rhyolite is the primary rock that forms from lava extruded from a volcano. It is similar in chemical composition to granite but with much smaller crystals. If the lava is very gaseous, then pumice might be formed (though
most pumice is associated with lava that is expelled rapidly into the air). If the lava oozing from the volcano cools quickly, it develops an amorphous internal structure like the glassy obsidian.

6. “Are those giant crystals shown in the photo in the Rohrig article real, or are they ‘Photo-shopped’? And why are the men all wearing orange jumpsuits?” Yes, the crystals are real. They were formed in mineral-saturated water over the course of more than 500,000 years, deep underground at extremely high temperatures. A mining company pumped the water out in order to extract minerals containing metals and discovered the cave. An average temperature of 50 °C (~122 °F) and 100% humidity in the mine require that explorers in the cave wear special suits to keep them cool, to prevent their succumbing to the extreme conditions. Even so, they can only stay in the cave for a short time (90 minutes, max).
Activities

Labs and Demos


Crystallization of supersaturated sodium acetate demonstration: This demonstration of the instant crystallization of a supersaturated solution of sodium acetate contains many lessons that can be applied to crystal formation. If done in the flask as written in the linked procedure, the students can see the crystals and feel the exothermic nature of the reaction by looking through and touching the flask. If the demonstration is done by slowly pouring the sodium acetate solution into a beaker containing a few crystals of sodium acetate in the bottom, you can build a tall, free-standing crystal mass that looks like the stalagmites in caves. (https://www.flinnsci.com/supersaturated-sodium-acetate-solution/dc91215/ or https://projects.ncsu.edu/project/chemistrydemos/Thermochem/SatNaOAc.pdf) A YouTube video of these demonstrations can be found here: https://www.youtube.com/watch?v=nvHrXr5Jaig.

Percent composition of lime in limestone labs: In this classroom laboratory experiment, students compare limestone samples by their lime (CaO) content. Two procedures are available in the referenced activity book: the first one, “How much Lime is in Limestone?” (pp 10–12, or the second one, “Are All Limestones Created Equal?” (pp 33–34). (http://www.wvgs.wvnet.edu/www/geoeduc/adaptiveactivities.PDF)

Simulations

How the speed of cooling of volcanic rock is affected by different variables: Five different variables that affect the rate of cooling of molten lava are tested in these virtual lab activities. Students explore and record data for the effects of size, surface area, grain size, composition, and composition of the surrounding rock on the speed of cooling. (http://www.esta-uk.net/cooling/)

Rock cycle animation: From flowing lava back to the melting of metamorphic rock, this animation has various items students can click on to see real life examples of what is being animated. (http://www.classzone.com/books/earth_science/terc/content/investigations/es0602/es0602page02.cfm?chapter_no=investigation)

Media
World of Chemistry’s video, “The Chemistry of Earth”: (28:40) This video discusses the process of rock formation and composition. The chemistry of the rocks and the uses of the minerals obtained from them is the primary focus.
(http://www.learner.org/vod/vod_window.html?pid=810)

Annenberg’s Earth Revealed “Minerals” episode: (28:54) A video about the minerals in rocks and how and why geologists study them is the theme of this segment of the Earth Science series, Earth Revealed.
(http://www.learner.org/vod/vod_window.html?pid=323)

Lessons and Lesson Plans

The geology of building stones: A set of five lessons with activities guide the student to explore the geology of the three rock types as found in a variety of building stones. The fifth activity “How Long Will My Gravestone last?” involves a field trip to a local graveyard where the students examine the headstones. Each lesson and activity can be done as a stand-alone lesson, allowing the teacher to choose one activity or all five. The link is to the index of pdfs. Look for “Building Stones 1”, which gives an overview of the series.
(http://www.earthlearningidea.com/English/Earth_Materials.html)

“Mineral Experts”: Four independent lessons, titled “Mineral Experts” 1, 2, 3, and 4 engage the student in different aspects of minerals. Each stand-alone lesson is accompanied with an activity. “Mineral Expert 1” is an introduction to mineral identification; “Mineral Expert 2” explains the tests used to identify minerals; while “Mineral Expert 3” is about minerals encountered in everyday life; and “Mineral Expert 4” is about why you should recycle your mobile phone. This might lead the students to start a school-wide phone recycling drive as an independent project.
(http://www.earthlearningidea.com/English/Earth_Materials.htm)

“Lessons from The Life Cycle of a Mineral Deposit” handbook: This is a teacher’s handbook, containing extensive geology background information for the teacher and several activities for students. Of particular interest to enhance the ChemMatters article might be Activity 5—“Extracting Metal (Cu) from a Rock” (page 14), Activity 7—“The Mineral Talc or ‘Rocks on Your Face’” (page 17), or Activity 8—“Make your Own Toothpaste” (page 18).

Projects and Extension Activities

Making Crystals: Students can make crystals in class to observe over several days, or this can be assigned as an optional at-home project. Instructions for an activity that has the students compare the difference between crystals grown with a granulated sugar solution to those grown with a powdered sugar solution can be found here: http://spark.ieee.org/2014-issue-1/the-surface-area-effect/, with accompanying pdf files here: http://tryengineering.org/sites/default/files/lessons/sugarnano_0.pdf.
Two other sites with instructions for growing crystals at home or in class are: https://www.scientificamerican.com/article/bring-science-home-crystals/ and https://www.thoughtco.com/growing-a-big-alum-crystal-602197.
**Starting a rock collection:** The information at this United States Geological Survey site will give students enough information to get started on a rock collection. Students could collect rocks and display them, as either an individual or in groups.

**“Sand or Rock? Finding out from 1000 km”, using the physical properties of substances to identify them:** This NASA activity could be assigned as an at-home project to students as individuals or to work on in groups. Students collect temperature data and graph it to compare the warming curves of sand vs. rock.
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://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”.

The chemistry of Mars’ rocks is presented, as well as the way the samples were analyzed. Author Stone discusses some of the findings from the NASA spacecraft Pathfinder and its robotic rover Sojourner and includes a sidebar with an informative discussion about basalt. (Stone, C. Clues from a Far Planet. ChemMatters, 1998, 16 (2), pp 7–9)

Good explanations of volcanic rock formation from magma are presented in this article on volcanoes. (Rohrig, B. Volcanoes—Forecasting the Fury. ChemMatters, 1999, 17 (4), pp 12–13)

Cave and sinkhole formation is the major topic of this article. The solubility of limestone, CaCO3, in the formation of caves and sinkholes is discussed. (Kimbrough, D. Caves: Chemistry Goes Underground. ChemMatters, 2002, 20 (2), pp 7–9)

For students particularly interested in diamonds, this article contains good information about diamonds and how they compare to graphite. (Sicree, A. Graphite vs. Diamond, Same Element but Different Properties. ChemMatters, 2009, 27 (3), pp 13–14)

Since talc is discussed in the Rohrig “Chemistry Rocks” article, students may find this article on mineral makeup interesting, as the makeup is made primarily from talc and mica powders. (Andrew, J. The Makeup of Mineral Makeup. ChemMatters, 2010, 29 (1), pp 16–17)

This article explains that the iridescence of opals can be attributed to the size and arrangement of internal silica particles. Some other silicates and their structures are also presented. (Argentine, C. Opals Playing with Color and Light. ChemMatters, 2013, 31 (3), pp 17–19)
The Teachers Guide for the above article contains considerable background information on rock formation, silicates, opals, gemstones, and minerals.

Lots of information on the internal bonding structure of diamonds can be found in this article. Also, there is considerable information on how fabricated diamonds are produced, followed by a comparison of natural vs manmade diamonds. (Eboch, C. An Explosion of Diamonds. ChemMatters, 2014, 32 (1), pp 14–16)

The Teacher’s Guide for “An Explosion of Diamonds” above contains a copy and explanation of Moh’s Hardness Scale, the classification scheme used to rate diamonds as gems, as well as several pictures illustrating the process of manufacturing diamonds. Under “Labs and Activities” there are links to crystal growing activities, as well as a “Teacher’s Guide for Mineral Education Activities” produced by the US Geologic Society.
Web Sites for Additional Information

Basic geology—a “gold mine” for teachers

This site provides a plethora of information pertaining to geology. In the left-hand margin, you will find topographical and geologic maps for each state. The Web site also provides additional teacher resources. (http://geology.com/)

The Science Daily Web site contains current research related to rocks. There are several interesting articles about geology current events linked in this Web site. (https://www.sciencedaily.com/search/?keyword=rocks#gsc.tab=0&gsc.q=rocks&gsc.page=1)

Rock formation

Further information on the rock cycle and rock formation is available at this Web site. Several links to Universe Today articles that could be used for further reading assignments can be found at the end of this article. (https://www.universetoday.com/46594/how-are-rocks-formed/)

While the initial focus of this Web site is quartz content in rocks, it also gives a great deal of information on rock formation. Several chemical equations illustrate the different types of rock formation. (http://www.quartzpage.de/gen_rock.html)

Minerals

This site contains extensive lists of minerals with their pictures. The “MINERALS”, “GEMSTONES”, “RESEARCH”, and “VIDEOS” tabs at the top of the Web site reveal great information for the teacher or student; clicking on the “RESEARCH” tab gives information on mineral formulas. (http://www.minerals.net/MineralMain.aspx) (http://www.minerals.net/resource/Chemical_Properties.aspx)

One can find extensive and in-depth information about minerals at this Wikipedia site. Sections on nomenclature and mineral chemistry contain good information about element substitution and polyhedral complexing in minerals. (https://en.wikipedia.org/wiki/Mineral)

Crystals and crystallization

This site provides information about the chemical process of crystallization. The information provided is not limited to geological processes, but they are mentioned. (https://en.wikipedia.org/wiki/Crystallization)

This Web site contains an explanation and definition of crystallization. At the end of the article are several links to instructions for growing crystals as well as some troubleshooting tips for when crystals are not growing as expected. (https://www.thoughtco.com/definition-of-crystallize-605854)
Moh’s hardness scale

The primary focus of this Web site is Moh’s hardness scale and how to use it in testing for a rock’s hardness. An extensive list of minerals and their respective hardness ratings is hyperlinked to a site that contains pictures, as well as the chemical formulas for the different minerals. [http://geology.com/minerals/mohs-hardness-scale.shtml]

This graph is a nice visualization of mineral bonding and the resultant hardness of the mineral. A two-paragraph explanation accompanies the graphic. [http://www.gly.uga.edu/railsback/Fundamentals/HardnessTrends29II.pdf]

Streak tests

This Web site contains instructions on performing streak tests on minerals. [http://geology.com/minerals/streak-test.shtml]

The Mineralogic Society of America’s “Mineral Identification Keys” can be accessed at this Web site. It provides several tables that contain the streak and hardness results for many minerals. [http://www.minsocam.org/msa/collectors_corner/id/mineral_id_keytia.htm]

Chemical bonding in rocks

This site contains explanations of metallic bonding as a function of low electron density and mobility. [https://en.wikipedia.org/wiki/Metallic_bonding]

The Britannica Web site provides a good explanation of chemical bonding as it applies to minerals in geology. [https://www.britannica.com/science/crystal/Types-of-bonds]

Gemstones

This is the homepage for an eleven-chapter book about gems, titled The Geology of Gems. Six labs, including one on Identification of minerals, are available on the Web site. [http://geologycafe.com/gems/index.html]

Beautiful pictures accompany a tremendous amount of information on a multitude of gemstones. Some stones have more information represented on the site than others. [http://geology.com/gemstones/]

Diamonds

This Web site provides extensive information about diamonds, including mineral descriptions, diamond mining, locations of diamonds on Earth, and myth-busting information on how diamonds are formed. There is also information on synthetic diamonds. [http://geology.com/diamond/]
This entry in the *Gem Encyclopedia* contains information about diamond as a gemstone. It explains how diamonds are graded and provides a world map depicting the locations of diamond mines. ([https://www.gia.edu/diamond](https://www.gia.edu/diamond))

**The Naica cave (“Cave of the Crystals”) in Mexico**

The Geology Page Web site contains a section describing the huge selenite (gypsum, CaSO₄•2H₂O) crystals that exist in the Naica underground cave in Chihuahua, Mexico. The site contains beautiful still photos of the crystals, as well as a video (4:53) of the cave. ([http://www.geologypage.com/2016/06/cave-of-crystals-giant-crystal-cave.html](http://www.geologypage.com/2016/06/cave-of-crystals-giant-crystal-cave.html))

There is an extensive Naica Web site, devoted entirely to the caves (there are several at various depths), that contains a series of 30 beautiful photos, several different videos, and descriptions of the research that is ongoing at the geologic site. This site is mostly in Spanish, so it would be useful for Spanish-speaking students. ([http://www.naica.com.mx/english/internas/interna1.htm](http://www.naica.com.mx/english/internas/interna1.htm))
About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.
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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.