

ChemMatters[®]

Demystifying Everyday Chemistry

Teacher's Guide

FEBRUARY 2020

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Teacher's Guide

Chernobyl's Legacy

February 2020

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Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write "A" or "D," indicating your Agreement or Disagreement with each statement. Complete the activity in the box.

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. Most of the people who left Chernobyl after the nuclear plant explosion have returned.
		2. The accident at Chernobyl occurred during a safety test.
		3. Temperatures inside the reactor during the explosion were as hot as parts of the Sun's atmosphere.
		4. The fuel in the reactor included U-238 from enriched uranium dioxide.
		5. A radioactive cloud blew across Northern Europe after the explosion.
		6. Isotopes of the same element have the same number of neutrons.
		7. When one mole of U-235 undergoes fission, the energy released can power about 400 average U.S. homes for a year.
		8. Nuclear reactors must have control rods to keep a chain reaction from occurring.
		9. Radioactive strontium can lead to bone cancer.
		10. The radioactive iodine released during the explosion still poses a health threat to people in Northern Europe.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Why is there an exclusion zone in Chernobyl?
2. How many nuclear reactors did Chernobyl have?
3. What type of fuel was used in the reactors in Chernobyl?
4. Describe the function of control rods in a nuclear reactor.
5. Nuclear reactions involve the nucleus of an atom. Which two subatomic particles are found in the nucleus of an atom?
6. What are isotopes? Give an example not cited in the article.
7. List the three radioisotopes that can result from the decay of U-235 in order of their half-lives.
8. Describe the process of fission in U-235.
9. If you start with a 30 g sample of I-131, how many grams of I-131 would there be after 16 days?
10. Explain how half a pound of U-235 can generate enough energy to power 400 average U.S. homes for a year.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. In 1979, the U.S. experienced a nuclear accident at Three Mile Island. Do some research and compare and contrast the two events.
2. Th-232 undergoes decay by emitting the following particles: alpha, beta, beta, alpha, alpha, alpha, alpha, beta, beta, alpha. What is the resulting isotope? Write out the entire decay series.
3. Do some research to conclude why alpha radiation is dangerous when ingested, beta particles cause damage to skin, and gamma radiation damages human cells.
4. Develop a list of at least three drawbacks and three benefits for using nuclear power as an energy source. Examine your list and explain whether or not we should continue to use nuclear power. Read the *Open for Discussion* article in this issue to help you decide.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe what happened during and after the explosion of the nuclear power plant at Chernobyl.

Nuclear Explosion at Chernobyl	
When did it happen?	
Where did it happen?	
What happened?	
How could the explosion have been prevented?	
What radioisotopes were produced?	
What kind of radiation was emitted?	
How were human beings affected?	

Summary: In the space below, or on the back of this paper, write three new things you learned about nuclear power plants and/or nuclear radiation.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Why is there an exclusion zone in Chernobyl?

The exclusion zone restricts access to the area around Chernobyl. The soil is still radioactively contaminated after the Chernobyl nuclear explosion.

2. How many nuclear reactors did Chernobyl have?

Chernobyl had four nuclear reactors.

3. What type of fuel was used in the reactors in Chernobyl?

Uranium dioxide, UO_2 , was the fuel in the reactors in Chernobyl.

4. Describe the function of control rods in a nuclear reactor.

Control rods slow chemical reactions because they absorb neutrons. This prevents the neutrons from reacting with additional uranium.

5. Nuclear reactions involve the nucleus of an atom. Which two subatomic particles are found in the nucleus of an atom?

Protons and neutrons are found in the nucleus of an atom.

s.

6. What are isotopes? Give an example not cited in the article.

Isotopes are atoms of the same element that have the same number of protons and electrons but different numbers of neutrons. To find more information about isotopes, visit the Isotopes Matter website at <https://applets.kcvs.ca/IPTEI/IPTEI.html>.

7. List the three radioisotopes that can result from the decay of U235 in order of their half-lives.

Iodine -131 half-life of eight days, strontium -90 half-life of 29 years, cesium-137 half-life of 30 years

8. Describe the process of fission in U-235.

In fission, the nucleus of a U-235 atom is bombarded by a neutron. This splits the nucleus to release a daughter nuclei, more neutrons, and energy.

9. If you start with a 30 g sample of I-131, how many grams of I-131 would there be after 16 days?

There would be 7.5 grams of I-131.

10. Explain how half a pound of U-235 can generate enough energy to power 400 average U.S. homes for a year.

When one atom of uranium goes through fission, the reaction releases a small amount of energy. When the reaction is repeated on the mole scale though, the self-sustaining reaction becomes significantly larger, producing exponentially more energy.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

1. In 1979, the U.S. experienced a nuclear accident at Three Mile Island. Do some research and compare and contrast the two events.

Three Mile Island information can be found here: <https://www.thebalance.com/three-mile-island-nuclear-accident-facts-impact-today-3306337>

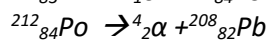
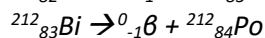
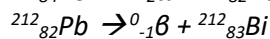
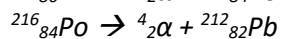
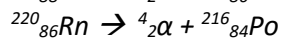
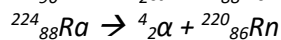
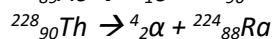
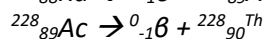
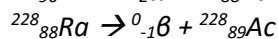
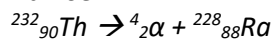
From the article: At 4 a.m. on March 28, a cooling circuit malfunctioned, allowing the primary coolant to overheat. The reactor shut down immediately, and the release valve opened for 10 seconds, which allowed enough coolant to escape to reduce pressure and heat. But the valve got stuck in the open position, and as a result, all the coolant was released. Unfortunately, there wasn't an instrument that could have alerted engineers that this had happened.

New coolant rushed into the tank, but the engineers now thought that there was too much, so they reduced the flow. The remaining coolant turned to steam. The fuel rods overheated, melting the protective coating, which released radioactive material into the coolant. When the steam was released, the radioactive contaminant was released into the surrounding area. Fortunately, the amount released was not enough to harm local food supplies, animals, or people.

Chernobyl scenario: Operator errors and design flaws in the reactor. A power surge caused the temperature and pressure of the reactor to rise dramatically creating a meltdown and explosion. Additionally, there were only eight control rods in the reactor when there should have been at least 15.

2. Th-232 undergoes decay by emitting the following particles: alpha, beta, beta, alpha, alpha, alpha, alpha, beta, beta, alpha. What is the resulting isotope? Write out the entire decay series.

Pb-208



3. Do some research to conclude why alpha radiation is dangerous when ingested, beta particles cause damage to skin, and gamma radiation damages human cells.

Alpha particles are two protons and two neutrons, so they are too large to penetrate human skin. If alpha particles are ingested through food or breathing contaminated air, the large particles can wreak havoc on the human body inside.

Beta particles are an electron expelled from a nucleus, so they are small high-energy particles that can penetrate pores in the skin.

Gamma rays are the most dangerous because it is pure energy, not matter. These rays can pass through human cells and cause damage.

4. **Develop a list of at least three drawbacks and three benefits for using nuclear power as an energy source. Examine your list and explain whether or not we should continue to use nuclear power. Read the *Open for Discussion* article in this issue to help you decide.**

Benefits: Source of low carbon energy, considered safe, produces a large amount of energy, low fuel costs

Drawbacks: Long-term waste disposal can be expensive, potential for nuclear accidents, initial building of nuclear reactor can be expensive

Graphic Organizer Rubric

If you use the Graphic Organizer 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

Additional Resources

Labs and demos

Twizzler Half-Life: In this lab activity students use licorice to understand and graph half-life and radioactive decay. <https://teachchemistry.org/classroom-resources/twizzler-half-life>

Fission Demonstration: In this demonstration, students use balloons to simulation fission. <http://nuclearconnect.org/in-the-classroom/for-teachers/what-is-fission>

Half-Life: In this lab, students visualize the random nature of atomic decay (or first order chemical reactions). It helps them answer the inevitable question of what happens when a decaying material reaches a single particle of the species. <https://teachchemistry.org/classroom-resources/half-life>

Using Dice to Explore Radioactive Decay: In this activity, students will use dice to simulate the radioactive "decay" of samples of two different elements with two different half-lives. <https://teachchemistry.org/classroom-resources/using-dice-to-explore-radioactive-decay>

Simulations

Half-Life Investigation: This simulation provides students with an opportunity to explore the decay of two unstable atom samples. <https://teachchemistry.org/classroom-resources/half-life-investigation-simulation>

Isotopes & Calculating Average Atomic Mass: <https://teachchemistry.org/classroom-resources/isotopes-calculating-average-atomic-mass-simulation>

Lessons and lesson plans

Nuclear Energy and the Three Mile Island Unit Two Accident: This set of lesson plans explores nuclear energy and the function of nuclear reactors. <http://www.efmr.org/edu/nuclear2009.pdf>

Projects and extension activities

Detecting Radiation in our Radioactive World: This teacher resource guide contains several hands-on activities designed to help students understand fission, radioisotopes, and decay chains. http://nuclearconnect.org/wp-content/uploads/2015/04/ANS-Teacher_Resource_Guide.pdf

Nuclear Energy Power Plants: In this activity, students will write a persuasive essay in which they state an opinion about whether the number of nuclear plants should be increased or decreased. <https://teachchemistry.org/classroom-resources/nuclear-energy-power-plants>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Atomic Structure – Isotopes
- Nuclear Chemistry
 - Alpha/beta/gamma decay
 - Half-lives
 - Pros/cons of nuclear power
 - Radioactive isotopes
 - Radiation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-8

Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-ETS1-3

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- PS1.C: Nuclear Processes
- ETS1.C: Optimizing the Design Solution

Crosscutting Concepts:

- Cause and Effect: Mechanism and explanation
- Scale, Proportion, and Quantity
- Energy and Matter

Science and Engineering Practices:

- Constructing explanations and designing solutions
- Analyzing and interpreting data
- Obtaining, evaluating, and communicating information

Nature of Science:

- Science is a human endeavor.

Student Reading Comprehension Questions – connections to NGSS Crosscutting Concepts:

- Q7 + Q9: Scale, Proportion, and Quantity
- Q4: Structure and Function
- Further Learning Q2: Scale, Proportion, and Quantity

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) at www.acs.org/chemmatters.

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- Alternative to the Anticipation Guide provided: Before reading, ask students if they have heard about Chernobyl. If students have never heard of the nuclear accident at Chernobyl, tell them there was a serious accident at the nuclear power plant in Chernobyl and ask them what questions they have about the accident or its aftermath. As they read the article, students should look for answers to their questions.
- Encourage students to watch the video (What Exactly Happened at Chernobyl? bit.ly/ACSReactions-Chernobyl) *after* they read the article. The video summarizes much of the information in the article and presents some animation to help students understand what happened.
- After students read “Chernobyl’s Legacy,” ask them to read “Open for Discussion: Can Nuclear Power Save the Planet” on page 4 of this issue of *ChemMatters*. Then ask students to list (or debate) the pros and cons of nuclear power.
- Have students do the Radioactivity Puzzle on the next page.

Radioactivity Puzzle

Sources of ionizing radiation

A lot of radioactive elements are either mined in a quarry (like uranium) or made in a lab (like americium). But there are a lot of things in your everyday life that are sources of ionizing radiation. Unscramble the words and phrases below to find some of them.

- 1) UNS
- 2) PASS
- 3) CHEWSAT
- 4) ANABANS
- 5) BEANSTEMS
- 6) ARLBIZ STUN
- 7) COTTONPURSE
- 8) KOMES DECOTTERS

Uses of ionizing radiation

Radiation from unstable isotopes has more uses than you think. Unscramble these words and phrases to find a few of those uses.

- 9) AMBERSINUS
- 10) PROWE LTSNAP
- 11) PACES ORBSEP
- 12) KALE CITEDNOTE
- 13) ARCENC MATTRENTE
- 14) CLAIMED ADIOSIGN
- 15) NUTRIMENTS INITIALZOSTER
- 16) ODOF INCANTATIONMODE

Answers

Sources of ionizing radiation

A lot of radioactive elements are either mined in a quarry (like uranium) or made in a lab (like americium). But there are a lot of things in your everyday life that are sources of ionizing radiation. Unscramble the words and phrases below to find some of them.

1) **Sun**

Fusion reactions in the sun's core emit powerful gamma (γ) radiation that travels to the Earth. This radiation is responsible for generating a steady supply of radioactive ^{14}C on the Earth's surface. Since the sun's rays cannot reach under the crust, scientists can measure the amount ^{14}C in buried objects to determine their age in a process called carbon dating.

2) **Spas**

Radon occurs naturally as a result of the radioactive decay of uranium in the soil. Because it is the densest gas known, it tends to accumulate in underground spaces, such as mines and basements. In the 1950s, a number of abandoned gold and uranium mines were converted into health spas that supposedly treat a variety of ailments via exposure to the radon in the mines. Despite the well-known dangers of radon, some of these spas continue to do business today.

3) **Watches**

The original glow-in-the-dark watches were painted with radium and a "phosphor" (phosphorescent compound) to achieve their luminescent effect. As the dangers of radium became known, the paints were replaced with tritium- and promethium-based paints. While they are also radioactive, they emit very low-energy beta (β) radiation, which is easily contained in the small quantities of a watch.

4) **Bananas**

About 0.01% of all potassium is the radioactive ^{40}K , which means that any high-potassium food, such as bananas, contains the radioactive isotope. However, your body only absorbs as much potassium as it needs and flushes the rest away. Even if you eat a truckload of bananas, your radiation exposure is about the same as eating one or two..

5) **Basements**

As mentioned above, radon occurs naturally in the soil, and it's density means that it accumulates in enclosed, underground spaces. Inhaling it puts the alpha (α)-emitter in your lungs, where is the leading cause of lung cancer after smoking. Because it is also odorless, colorless, and tasteless, the EPA recommends testing your basement regularly for radon.

6) **Brazil nuts**

Brazil nut trees have deep roots that absorb naturally-occurring radium from the soil. The radium accumulates in the nuts. Brazil nuts are also high in potassium, making them one of the most radioactive foods available. Fortunately, the radioactivity of Brazil nuts is closely monitored to ensure the ones you buy in the store are safe.

7) **Countertops**

Stone countertops, like granite and marble, may contain veins of radioactive uranium and thorium, which release radon in their decay products. While the composition of natural stone varies, the amount of radiation exposure from any given countertop is too small to measure by the average consumer.

8) **Smoke detectors**

Smoke detectors contain a small amount of ^{241}Am , which emits a steady stream of α particles. When the stream is disrupted by the presence of smoke, an alarm is triggered. The plastic casing of the detector is more than enough to protect you from the radiation—just keep it intact!

Uses of ionizing radiation

Radiation from unstable isotopes has more uses than you think. Unscramble these words and phrases to find a few of those uses.

9) **Submarines**

Some US Navy submarines, and a few surface ships, rely on on-board nuclear reactors for power. These vessels can then run for 25 years or more without refueling, even at high speeds. In contrast, diesel- and battery-powered ships must refuel every few days or even hours. Due the expense of building and maintaining nuclear vessels, only about 140 exist today.

10) **Power plants**

There are about 400 nuclear reactors in the world that supply electricity to local communities. Nuclear energy is often considered an environmentally-friendly power source, because it emits no CO_2 . It is also energy-dense: a 10 g uranium fuel pellet produces the same power as 150 barrels of oil. However, disposing of nuclear waste is a common problem, and plant accidents can have huge impacts.

11) **Space probes**

Solar power is great for satellites that orbit the earth, but probes that go deep into space or behind planets or moons wind up too far away for it to be effective. Instead, a golf-ball sized nuclear reactor (usually powered by something like ^{238}Pu) provides enough power to keep space probes going for decades, along with enough heat to keep the circuits from freezing over. Probes such as New Horizons, Voyager, and Curiosity, all run on nuclear power.

12) Leak detection

Gas & oil pipelines, metal welding, boilers, and vehicle parts are often inspected for cracks or leaks using ^{192}Ir or ^{60}Co . These isotopes emit γ rays that can be used like X-rays. Because radioactive decay is spontaneous, the detectors don't need batteries to function; they are also small and can find leaks in tight corners.

13) Cancer treatment

Radioactive materials can cause cancer by damaging DNA in healthy cells, but they can also be used to destroy cancerous cells in the same manner. Radioactive elements that are picked up by specific organs can be given by injection or pill, such as ^{131}I for thyroid cancer. Isotopes may also be attached to molecules that are attracted to the organ or type of cancer. Sometimes tiny "seeds" of a radioisotope are implanted in or near a tumor, such as ^{103}Pd for treatment of early-stage prostate cancer.

14) Medical diagnosis

Radioactive isotopes can be injected into a patient, where they are taken up by certain organs. Scanners track then track the isotopes to provide a far more complete picture of the target organ than would otherwise be possible. For example, ^{99}Tc can be used to image the heart, ^{131}I for the thyroid, and ^{81}Kr for the lungs.

15) Instrument sterilization

Humans can handle small amounts of radiation because our bodies can easily replace a few cells damaged by ionizing radiation. Single-celled organisms are not so lucky, which is why surgical equipment can be treated with ^{60}Co to sterilize it.

16) Food decontamination

In the same way that ^{60}Co sterilizes equipment, it can also be used to decontaminate food. The low amounts of energy needed to kill bacteria on food are not enough to damage the food itself or make it radioactive.

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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. Earth would be lifeless without iron.
		2. By weight, iron is one of the least abundant elements in the universe.
		3. As a star's core starts producing iron, the star begins to collapse, eventually forming a supernova that releases iron into space.
		4. Seismic waves were used to confirm the hypothesis that most of Earth's core is made of iron.
		5. Earth's core is very cool by comparison to Earth's surface.
		6. Earth's magnetic field protects life on Earth in several ways.
		7. Most refined iron is processed into steel.
		8. Steel is made of iron and carbon.
		9. Iron processing helps remove greenhouse gases from the atmosphere.
		10. Only animals need iron to survive; plants and bacteria do not need iron.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What are some of the physical properties of iron?
2. Describe how a metallic bond works.
3. What was the procedure that determined that Earth's core was made of iron?
4. Give examples of how iron is needed for plants and animals to live.
5. There are two ways to get the required iron to live. What are those two ways?
6. List the effects of having too much and too little iron in our bodies.
7. Describe an ionic bond. What would be some properties in ionic bonds that are different from metallic bonds?
8. Describe the process of converting iron oxides to pure iron. How could this process be detrimental to the environment?
9. There is very little pure iron in Earth's crust. How is iron typically found? What does that tell you about the reactivity of iron, compared to other metals that are typically found in pure form? (Hint: look up the activity series of metals.)
10. Sketch particle diagrams of pure iron, and of iron/carbon (steel) alloy. Use these diagrams to show how the alloy is stronger than pure iron.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. The core of the planet is over 10,000 °F. Research the ways people are using this heat as an alternative energy source (called geothermal energy).
2. Research and describe how seismic waves are detected and measured. How do these waves travel through the planet?
3. Research and report any alternative methods to produce steel that reduces the CO₂ production, or how steel producers try to limit the amount of CO₂ produced.
4. Research and list what metals are found in the human body. What are the primary uses/functions of these metals?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the importance of iron.

<p>How is iron formed?</p>	
<p>Where is iron found on Earth?</p>	
<p>What ores contain iron?</p>	
<p>How is iron obtained from ores?</p>	
<p>What compounds in living things contain iron?</p>	
<p>How can you obtain iron from food?</p>	
<p>What can happen if you do not eat enough iron?</p>	

Summary: On the back of this paper, write a tweet (280 characters or less) describing the importance of iron.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What are some of the physical properties of iron?

Silver/grey, malleable, ductile, conducts electricity and heat. The atoms are held closely together by metallic bonds.

2. Describe how a metallic bond works.

Metallic bonds happen when the electron shells of the metal atoms overlap, and the electrons move freely throughout the atoms.

3. What was the procedure that determined that Earth's core was made of iron?

Scientists measured the seismic waves, created by earthquakes, and how they travelled through Earth.

4. Give examples of how iron is needed for plants and animals to live.

For plants, enzymes that contain iron are needed to help them produce chlorophyll. For humans, iron is needed in the blood cells as hemoglobin. This chemical helps transport oxygen throughout the body, and transports carbon dioxide out of the body to the lungs.

5. There are two ways to get the required iron to live. What are those two ways?

Two forms of needed iron are heme and non-heme. The heme is found in meat, poultry and fish. The non-heme is found in dark green leafy vegetables, as well as cereals, lentils, beans and rice.

6. List the effects of having too much and too little iron in our bodies.

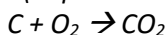
Too much iron in the body will lead to iron poisoning, and hemochromatosis (causing fatigue and joint pain and other symptoms). Too little iron causes anemia, which results in fatigue and shortness of breath.

7. Describe an ionic bond. What would be some properties in ionic bonds that are different from metallic bonds?

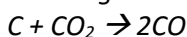
Ionic bonds occur when electrons are transferred from metal atoms to nonmetal atoms, creating positive and negative attractions, which form ordered crystal structures. One difference from metallic bonds is that ionic bonds cannot conduct electricity or heat, because there are no free flowing electrons. The ionic bonds also create a structure that cannot be malleable or ductile, because the ions remain in a fixed position.

8. Describe the process of converting iron oxides to pure iron. How could this process be detrimental to the environment?

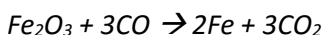
Coke (impure carbon) is reacted with oxygen to make carbon dioxide.



The resulting carbon dioxide reacts with more coke to make carbon monoxide.



The carbon monoxide reacts with the iron ore to make pure iron and carbon dioxide



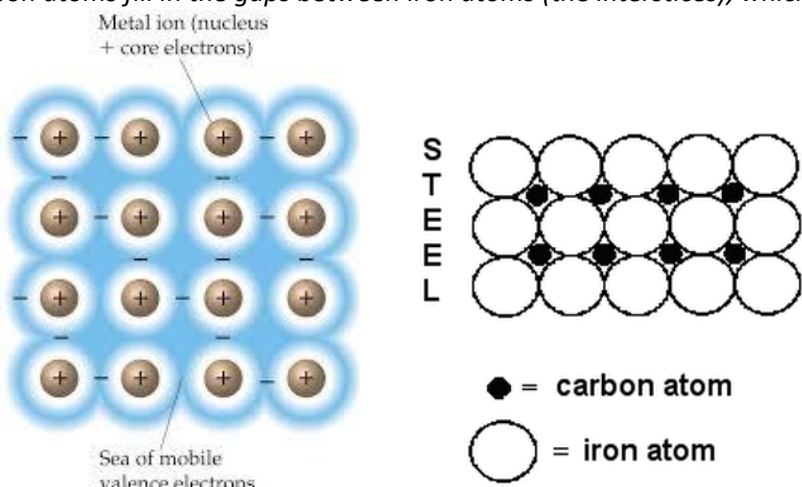
This process is not environmentally friendly because CO₂ (a greenhouse gas) is produced. Also, there may be some excess CO remaining (a poisonous gas). Also, some of the impurities of the coke could be hazardous to the environment.

9. There is very little pure iron in the earth's crust. How is iron typically found? What does that tell you about the reactivity of iron, compared to other metals that are typically found in pure form? (Hint: look up the activity series of metals.)

Iron is typically found as iron oxide. Very little pure iron is found in nature. Iron is not very stable reactivity-wise, compared to other metals. It is easy for oxygen to react with it. (Iron is oxidized).

10. Sketch particle diagrams of pure iron, and of iron/carbon (steel) alloy. Use these diagrams to show how the alloy is stronger than pure iron.

Carbon atoms fill in the gaps between iron atoms (the interstices), which gives the alloy stronger structure.



Questions for Further Learning

1. The core of the planet is over 10,000 °F. Research the ways people are using this heat as an alternative energy source (called geothermal energy).

Get started with geothermal energy basics: www.energy.gov/eere/geothermal/geothermal-basics

2. Research and describe how seismic waves are detected and measured. How do these waves travel through the planet?

Get started with this article about seismic waves: www.sciencelearn.org.nz/resources/340-seismic-waves

3. Research and report any alternative methods to produce steel that reduces the CO₂ production, or how steel producers try to limit the amount of CO₂ produced.

Get started with this C&EN article about this: <https://cen.acs.org/environment/greenhouse-gases/Steel-plant-waste-mop-CO2/97/web/2019/08>

4. Research and list what metals are found in the human body. What are the primary uses/functions of these metals?

You can point students here to get started: <https://askabiologist.asu.edu/content/atoms-life>

Graphic Organizer Rubric

If you use the Graphic Organizer 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

Additional Resources

Labs and demos

Metallic Breakfast: In this lab, students will separate iron filings from iron-fortified breakfast cereals. Students will use the recorded data to conduct percent composition calculations. <https://teachchemistry.org/classroom-resources/metallic-breakfast>

Iron Nail Redox: In this lab, students perform a simple redox reaction using an iron nail and copper(II) chloride solution. They will consider both quantitative and qualitative data collected during the reaction in order to attempt to explain what happened. <https://teachchemistry.org/classroom-resources/inquiry-redox-investigation>

Separating Mixtures: In this lab, students devise their own method to separate a mixture of sand, salt, poppy seeds, and iron filings. <https://teachchemistry.org/classroom-resources/separation-of-a-mixture>

Mineral Investigation: In this lab, students will put their problem solving skills to work as a team to determine how many specific samples of ore can be made from a lode equivalent to the size of their classroom. <https://teachchemistry.org/classroom-resources/mineral-investigation>

Other Resources

A clearer look at how iron reacts in the environment: <https://www.anl.gov/article/a-clearer-look-at-how-iron-reacts-in-the-environment>

Steel production & environmental impact: <http://www.greenspec.co.uk/building-design/steel-products-and-environmental-impact/>

Environmental impact of steel production processes: <https://www.jernkontoret.se/en/the-steel-industry/production-utilisation-recycling/environmental-impact-of-the-processes/>

Periodic Table of Videos – Iron: <https://youtu.be/euQUgp5AY-Y>

Infographic- Iron: Blood, Mars, and magnetic fields: <https://www.compoundchem.com/2019/05/03/iypt026-iron/>

Infographic – The Chemistry of Spinach: <https://www.compoundchem.com/2018/07/17/spinach/>

Metals in the body: <https://www.livescience.com/18247-metals-human-body-health-nigms.html>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Chemistry Basics – Elements
- Molecules & bonding – alloys; metallic bonding; ionic bonding; molecular structure
- Reactions & Stoichiometry – combustion

Correlations to Next Generation Science Standards

This article can be used to achieve the following performance expectations of NGSS:

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.

HS-ESS1-3.

Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ESS1.A: The Universe and Its Stars

Crosscutting Concepts:

- Patterns
- Cause and Effect: Mechanism and explanation
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence

Nature of Science:

- Scientific knowledge is based on empirical evidence.
- Scientific knowledge assumes an order and consistency in natural systems

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards at www.acs.org/chemmatters](http://www.acs.org/chemmatters).

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- Alternative to the Anticipation Guide: Before reading, ask students why iron is important to life on Earth.
- After reading, ask students what they found most interesting or surprising from reading the article.
- After reading, ask students to identify occurrences of iron in their day-to-day lives. Classify each occurrence of iron as an element or an ion.

ChemMatters™

Demystifying Everyday Chemistry

Teacher's Guide

Chemistry Takes to the Skies

February 2020

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This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
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Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

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
		11. World War I pilots used skywriting to communicate with one another.
		12. Skywriting is created with smoke.
		13. The gaseous products expelled from the exhaust pipe of a jet are white.
		14. Contrails and skywriting are chemically the same.
		15. Jet fuel has a higher boiling point than gasoline.
		16. Smoke is an aerosol, with solid or liquid particles suspended in air.
		17. Words written with skywriting remain legible for 3-4 hours.
		18. When the letters from skywriting dissipate, the particles evaporate.
		19. There are thousands of experienced skywriters in the world today.
		20. A nanometer is larger than a micrometer.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

- Classify each of the following as either chemical or physical processes. For each, explain your answer.
 - Combustion
 - Fractional distillation
- Examine the figure on page 13 and answer the following questions.
 - What is distillation?
 - Why is the process in this figure called fractional distillation?
 - Why must crude oil go through this process in order to be useful?
 - Describe the relationship between molecular mass, density, and boiling point for hydrocarbons.
 - Use molecule structure to explain the relationship between molecular mass and boiling point.
- If there are seven carbons in an alkane, then what is its molecular formula? Write the balanced chemical equation for the combustion of this seven-carbon compound.
- What is the molecular mass of kerosene?
- When we see a contrail in the sky, it is not the water vapor from the combustion reaction that we see. Explain what happens to allow us to see this contrail.
- Would you expect a contrail to last longer on a humid day or a dry day (assuming the same temperature)? Explain.
- An aerosol is one subcategory of a colloid. Colloids have particles of one substance with a size between 1 and 1000 nm dispersed in another substance. Each part of this mixture can be of any phase and the phase combination is what classifies them into their subcategories. Use the table and the figure on page 14 to answer the questions below:
 - How many nanometers are in a micrometer?
 - How many nanometers are in a kilometer?
 - How many nanometers are in a millimeter?

Student Reading Comprehension Questions, cont.

8. Why don't skywriters simply rely on contrails to do their writing, rather than adding in other substances?
9. Why do contrails and the smoke from skywriting dissipate fairly quickly, even on a day without any wind?

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. Which would make more water when combusted in oxygen, 1 mole of $C_{10}H_{22}$ or 1 mole of $C_{15}H_{32}$? Explain, but do not use calculations.
2. To what total volume will the water vapor from the combustion of 1.00 liter of kerosene spread when released in the atmosphere at 30,000 feet, where the temperature is $-47.8^{\circ}C$ and the pressure is 0.298 atm? The density of kerosene is 0.800 g/cm^3 .
3. Adiabatic processes are those during which no heat is exchanged between the system and the surroundings. This term is often used as an approximation for processes that are very fast and have no heat exchange while the process is occurring, even if heat is eventually exchanged. Fans of Superman often attempt to describe the science of his superpowers. Use the idea of adiabatics to explain how Superman can freeze things with his breath.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to compare contrails and skywriting.

	Contrails	Skywriting
How produced (chemical equation)		
Composition of vapor		
Atmospheric conditions needed		
Height of plane		
Appearance		

Summary: In the space below, or on the back of this paper, write a short email to a friend explaining the difference between contrails and skywriting.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

- Classify each of the following as either chemical or physical processes. For each, explain your answer.
 - Combustion**
Chemical process. The bonds in the original compounds are broken and new bonds are formed.
 - Fractional Distillation**
Physical process. This works on evaporation and condensation, both of which are physical processes. No bonds are broken or formed.
- Examine the figure on page 13 and answer the following questions.
 - What is distillation?**
Boiling a liquid and then catching the vapor in a separate by cooling it down. This is a way of separating parts of a mixture by boiling point.
 - Why is the process in this figure called fractional distillation?**
Crude oil is made of many different compounds. Each boiling range is specific to a fraction of the molecules in the mixture, so each range is separately condensed.
 - Why must crude oil go through this process in order to be useful?**
Most uses for substances require specific molecules. Crude oil is a mixture of many different compounds that can be used in very different ways.
 - Describe the relationship between molecular mass, density, and boiling point for hydrocarbons.**
A lower molecular mass has a lower density and a lower boiling point. All three are positively correlated.
 - Use molecule structure to explain the relationship between molecular mass and boiling point.**
Smaller molecules have lower polarizability, so their London dispersion forces are not as attractive as larger molecules with higher polarizability, therefore smaller molecules have lower boiling points and larger molecules have higher boiling points.
- If there are seven carbons in an alkane, then what is its molecular formula? Write the balanced chemical equation for the combustion of this seven-carbon compound.
 C_7H_{16}
 $C_7H_{16} + 11 O_2 \rightarrow 7 CO_2 + 8 H_2O$
- What is the molecular mass of kerosene?**
170.34 amu (using molecular mass strictly) or 170.34 g/mol (using molar mass)
- When we see a contrail in the sky, it is not the water vapor from the combustion reaction that we see. Explain what happens to allow us to see this contrail.**
The water vapor from combustion spreads into the atmosphere and condenses into liquid, then freezes into solid around small particles in the atmosphere, where water vapor from the atmosphere also crystallizes. It is the frozen water around the particles that we see as the contrail.
- Would you expect a contrail to last longer on a humid day or a dry day (assuming the same temperature)? Explain.**
It should last longer on a humid day because there are more water molecules in the atmosphere to crystallize onto the particles, making them last longer before dissipating.

7. An aerosol is one subcategory of a colloid. Colloids have particles of one substance with a size between 1 and 1000 nm dispersed in another substance. Each part of this mixture can be of any phase and the phase combination is what classifies them into their subcategories. Use the table and the figure on page 14 to answer the questions below:
- How many nanometers are in a micrometer?
1000 micrometers = 1 nm
 - How many nanometers are in a kilometer?
 10^{12} nanometers = 1 km
 - How many nanometers are in a millimeter?
 $1,000,000$ nm = 1 mm
8. Why don't skywriters simply rely on contrails to do their writing, rather than adding in other substances? They fly at 10,000 feet, rather than 30,000 feet, so the air isn't cold enough to crystallize enough water to make it very visible.
9. Why do contrails and the smoke from skywriting dissipate fairly quickly, even on a day without any wind? All molecules are in motion all the time. Over time, the air molecules and the molecules in the contrail or smoke will run into each other and eventually mix and spread.

Questions for Further Learning

1. Which would make more water when combusted in oxygen, 1 mole of $C_{10}H_{22}$ or 1 mole of $C_{15}H_{32}$? Explain, but do not use calculations.

$C_{15}H_{32}$ has more hydrogens that will turn into H_2O during combustion, so it will make more water.

2. To what total volume will the water vapor from the combustion of 1.00 liter of kerosene spread when released in the atmosphere at 30,000 feet, where the temperature is -47.8°C and the pressure is 0.298 atm? The density of kerosene is 0.800 g/cm^3 .

$$V = \frac{nRT}{P} = \frac{[(1.00\text{L} \times \frac{1000\text{mL}}{1\text{L}} \times \frac{0.800\text{g}}{\text{mL}})(\frac{1\text{mol}}{170.34\text{g}})] \times 0.0821\text{ L} \cdot \text{atm}/\text{mol} \cdot \text{K} \times 225.4\text{K}}{0.298\text{atm}} = 292\text{L}$$

3. Adiabatic processes are those during which no heat is exchanged between the system and the surroundings. This term is often used as an approximation for processes that are very fast and have no heat exchange while the process is occurring, even if heat is eventually exchanged. Fans of Superman often attempt to describe the science of his superpowers. Use the idea of adiabatics to explain how Superman can freeze things with his breath.

Student answers will vary.

Graphic Organizer Rubric

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

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4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
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1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources

Labs and demos

Whoosh bottle: In this demonstration, you will show students how hydrocarbons combust and that the products are no longer combustible. Do not let students do this experiment, it must be done as a demo.

<https://www.flinnsci.com/api/library/Download/bf2f0d16dd86411ea26eb0cb687dc593>

Simulations and Videos

Gas laws: <https://phet.colorado.edu/en/simulation/gas-properties>

Balancing chemical equations: <https://phet.colorado.edu/en/simulation/balancing-chemical-equations>

Video of phase diagram basics. <https://www.youtube.com/watch?v=ejg27ozbPA8>

Lessons and lesson plans

Simulation Activity: Balancing Chemical Equations: In this activity, students will learn how to count atoms and how to balance chemical equations using a simulation and games from PhET Interactive Simulations.

<https://teachchemistry.org/classroom-resources/simulation-activity-balancing-chemical-equations>

What Type of Mixture is Paint: In this lesson students will use simple laboratory tests to characterize differences between solutions, colloids, and suspensions. They will then apply those tests to paints to classify them as specific types of mixtures. <https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>

Projects and extension activities

An extension of combustion could be done to compare the theoretical fuel efficiency of various hydrocarbons or alcohols, like in this AACT lesson: <https://teachchemistry.org/classroom-resources/evaluating-fuels>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Chemistry basics – Chemical and Physical changes; Physical properties
- Gases – Temperature
- Quantitative Chemistry – SI units
- Solutions – Mixtures
- States of Matter – Boiling point

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS2-6.

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-ETS1-3

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ETS1.C: Optimizing the design solution

Crosscutting Concepts:

- Cause and Effect: Mechanism and explanation
- Structure and Function

Science and Engineering Practices:

- Developing and using models
- Constructing explanations (for science) and designing solutions (for engineering)

Nature of Science:

- Scientific knowledge is based on empirical evidence.
- Scientific knowledge assumes an order and consistency in natural systems.

Student Reading Comprehension Questions – connections to NGSS Crosscutting Concepts:

- Q2: Patters + Systems & System Models
- Q7: Scale, Proportion, and Quantity + Systems & System Models

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) at www.acs.org/chemmatters.

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- Alternative to the Anticipation Guide: Before reading, ask students if they have seen contrails, where they have seen them, and what they think they are made of. Also ask them if they have seen skywriting, and what questions they have about skywriting. As they read, students should record information they find interesting and look for answers to their questions.
- Show (or ask students to watch) the three-minute video clip referenced in the article to learn more about contrails.
- This lesson could be a phenomenon-based lesson, with skywriting or contrails being the phenomenon to investigate through combustion reactions.
- Ask students what they found most interesting from reading article.
- Using phase diagrams, pressure and temperature are easy to find at various altitudes. This can be used to interact with a phase diagram to learn all of its parts and to explain why the water condenses and then crystallizes in the upper atmosphere to make a contrail.

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Teacher's Guide

Crystal Caves

February 2020

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Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

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. Huge gypsum crystals were discovered in a cave under a mountain rich in lead, zinc, and silver ore.
		2. The cave where the crystals were found is cold and dry.
		3. Gypsum is mostly calcium sulfate.
		4. Gypsum crystals grow from tiny starting crystals of gypsum.
		5. Gypsum’s crystal structure includes water molecules.
		6. Understanding crystal growth could help combat mineral growth on equipment at desalination plants.
		7. The age of the crystals in the cave was determined by carbon dating.
		8. The Cave of Crystals (with larger crystals) is found at a shallower depth than the Cave of Swords (with smaller crystals).
		9. Visitors to the cave can stay for up to four hours.
		10. In order to preserve the gigantic crystals, the crystals must be removed from the cave.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Briefly describe how the crystal formations in Crystal Cave formed.
2. Compare and contrast the following: unsaturated solution, saturated solution, and supersaturated solution.
3. Define nucleation and give an example.
4. What environmental conditions caused the crystals to grow to their tremendous size?
5. What are the potential benefits of conducting research on the conditions in the cave and on mineral deposits?
6. Explain how a chemist could create a supersaturated solution in a laboratory. What equipment would be needed?
7. Rock candy is an example of a product created from a supersaturated solution. Research and explain the process of making rock candy.
8. Explain, using your knowledge of chemical principles, why generally solubility increases with increasing temperature.
9. Mineral deposits form in many different colors. What causes the color differences between various minerals?
10. Compare and contrast the formation of the minerals in the article to how diamonds are formed.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answer on another piece of paper if needed.

Suppose the Mexican government wanted to make “Crystal Cave” a tourist destination to increase tourism revenue. You have been put in charge of the team who is tasked with making Crystal Cave a safe, accessible, place for tourists to visit and enjoy the beauty of the caves. Devise a detailed plan explaining how you would alter a dangerous cave into a civilian-friendly display for all to enjoy.

Things to consider: How would you access the cave? How would you control the climate in the cave and not interrupt the crystal formation? How would civilians navigate the cave? How would you ensure the structural integrity of the cave?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to compare the Cave of Crystals and Cave of Swords described in the article.

	Cave of Crystals	Cave of Swords
Size of crystals		
Type of crystals		
Depth of cave		
Location of cave		
How the crystals formed		
Time involved for crystal formation		
What limited the growth of the crystals		

Summary: On the back of this sheet, write a one-sentence summary (18 words or less) describing what you learned about crystal growth.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Briefly describe how the crystal formations in Crystal Cave formed.

Approximately 26 million years ago, a mound of magma strained upward through the earth and forced hot, mineral rich waters into caverns and gaps in the mountain's limestone. The supersaturated solution of mineral rich water cooled very slowly, allowing large crystals to form on nucleation sites.

2. Compare and contrast the following: unsaturated solution, saturated solution, and supersaturated solution.

Unsaturated Solution: A solution in which more solute can be added and dissolved in the solvent.

Saturated Solution: A solution in which no more solute can be dissolved in the solvent.

Supersaturated Solution: An unstable solution which contains more dissolved solute than the predicted amount in a saturated solution.

3. Define nucleation and give an example.

Nucleation, the initial process that occurs in the formation of a crystal from a solution in which a small number of molecules become arranged in a pattern characteristic of a crystalline solid, forming a site upon which additional particles are deposited as the crystal grows.

4. What environmental conditions caused the crystals to grow to their tremendous size?

Warm water, mineral rich water, nucleation sites, and a perfect cooling rate. If the water would have cooled too fast, the minerals would have been smaller as in the "Cave of Swords"

5. What are the potential benefits of conducting research on the conditions in the cave and on mineral deposits?

The mineral research could help mining companies prevent mineral deposits on their machinery and equipment, thus prolonging the life of the equipment and saving the company money.

6. Explain how a chemist could create a supersaturated solution in a laboratory. What equipment would be needed?

One would need a solute (example sodium acetate), a solvent (example water), a beaker or flask, and a hot plate. The student/teacher would make a saturated solution of sodium acetate and water with excess sodium acetate remaining in solution (undissolved) at room temperature. The solution should be slowly heated while stirring until all the solute dissolves. Once all the solute is completely dissolved the solution should be cooled slowly. A simple agitation of the solution or the addition of one granule of the solute would be enough to cause the supersaturated solute to come out of solution and crystalize

7. Rock candy is an example of a product created from a supersaturated solution. Research and explain the process of making rock candy.

1) Put water in a pot and bring to boil on a stove or hotplate

2) Slowly add sugar until no more sugar will dissolve

3) Let solution cool to room temperature.

4) Pour solution through a strainer to remove undissolved sugar.

5) Add food coloring or flavoring

6) Pour solution in a jar or cup

- 7) Tie a clean string around a pencil, wooden dowel, or similar object that will allow the string to hang in the solution
- 8) Let the string soak in the solution for about a week, undisturbed.
- 9) Take the string out and enjoy the candy.

8. Explain, using your knowledge of chemical principles, why generally solubility increases with increasing temperature.

Answers may vary. Simply stated, a higher temperatures molecules have increased kinetic energy and are vibrating and moving faster. This increased kinetic energy, or vibration, allow solvent molecules to more effectively break down solute molecules causing them to dissolve or dissociate.

9. Mineral deposits form in many different colors. What causes the color differences between various minerals?

Color differences in minerals are caused by of the wavelengths of visible light that are absorbed and emitted from the different minerals. Depending on the composition of the mineral, and which elements (different arrangement of electrons) they contain and what patterns they form, difference light waves will be absorbed and emitted causing different colors.

10. Compare and contrast the formation of the minerals in the article to how diamonds are formed.

Mineral deposits in Crystal Cave required mineral rich water, cavernous areas, high temperatures, and slow cooling.

Diamonds need incredible pressure and temperature deep in the earth's mantle.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

Suppose the Mexican government wanted to make “Crystal Cave” a tourist destination to increase tourism revenue. You have been put in charge of the team who is tasked with making Crystal Cave a safe, accessible, places for tourists to visit and enjoy the beauty of the caves. Devise a detailed plan explaining how you would alter a dangerous cave into a civilian friendly display for all to enjoy.

Things to consider: How would you access the cave? How would you control the climate in the cave and not interrupt the crystal formation? How would civilians navigate the cave? How would you ensure the structural integrity of the cave?

Answers will vary. Some things to consider are ease of access to the mine, how the tourist will get down to the cave, temperature control and comfort in the cave without damaging the crystals, safe navigation of the cave, structural integrity of the cave, preserving the cave with the increased traffic.

Graphic Organizer Rubric

If you use the Graphic Organizer 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

Additional Resources

Labs and demos

Mineral Investigation: Minerals are a great way to teach percent composition.

<https://teachchemistry.org/classroom-resources/mineral-investigation>

Supersaturated Solution Lab: Lab in which students create their own supersaturated solution.

<https://teachchemistry.org/classroom-resources/winter-crystals>

Chemistree: In this lab, students will prepare a solution to observe a physical change.

<https://teachchemistry.org/classroom-resources/chemistree>

Crystallization of Sugar: In this demonstration, students will observe how to make rock candy in order to understand how sugar crystals form. They will be able to explain what a supersaturated solution is and how it is relevant to sugar crystallization. <https://teachchemistry.org/classroom-resources/crystallization-of-sugar>

Saturated Solutions: An Engagement Activity: In this demonstration, students will observe salt dissolving in water and participate in a think-pair-share activity using teacher-led questions. It is intended to be an introduction to solutions, particularly saturation. <https://teachchemistry.org/classroom-resources/saturated-solutions-an-engagement-activity>

Lessons and lesson plans

Earth Chemistry: An excellent resource for more information on minerals and Earth Chemistry. Also helpful if you need a refresher before implementing the article in your class.

<https://teachchemistry.org/periodical/issues/september-2019/teaching-earth-chemistry-1>

Particle Modeling of Hand Warmers: In this lesson, students will create a particulate model of matter that explains energy changes and transfer during a physical process, such as the crystallization of a solid from a supersaturated solution. <https://teachchemistry.org/classroom-resources/particle-modeling-of-hand-warmers>

Other Resources

Mineral Chemistry Webinar: A webinar on minerals and chemistry to reinforce or expand on information in the article. <https://teachchemistry.org/professional-development/webinars/the-rocky-road-to-chemistry>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Chemistry Basics
 - Physical properties
 - Inference
- Solutions
 - Solubility
 - Solute/solvent
- States of Matter

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-5.

Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

HS-ESS2-5.

Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ESS2.C: The Roles of Water in Earth's Surface Processes

Crosscutting Concepts:

- Cause and Effect: Mechanism and explanation.
- Scale, Proportion, and Quantity
- Structure and Function
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Asking questions (for science) and defining problems (for engineering)

Nature of Science:

- Scientific knowledge is based on empirical evidence.
- Science addresses questions about the natural and material world

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) at www.acs.org/chemmatters.

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- Alternative to Anticipation Guide: Before reading, ask students if they have ever grown crystals (like rock candy) and how crystals form. As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students what conditions promoted the growth of the giant gypsum crystals.

About the Teacher's Guide

Teacher's Guide team editors Dusty Carroll, Scott Hawkins, Matt Perekupka, and Jennifer Smith created the Teacher's Guide article material. Susan Cooper prepared the anticipation, reading guides, and connections to standards.

Christine Suh (Managing Editor), Emily Abbott (Administrative Editor), and Lis Gallegos (Production Editor) coordinated the production and development of the Teacher's Guides.

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