

**Teacher’s Guide**

**Crystal Caves**

***February 2020***

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Activate students’ prior knowledge and engage them before they read the article.

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These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps 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.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 9](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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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. |
|  |  | 1. The cave where the crystals were found is cold and dry. |
|  |  | 1. Gypsum is mostly calcium sulfate. |
|  |  | 1. Gypsum crystals grow from tiny starting crystals of gypsum. |
|  |  | 1. Gypsum’s crystal structure includes water molecules. |
|  |  | 1. Understanding crystal growth could help combat mineral growth on equipment at desalination plants. |
|  |  | 1. The age of the crystals in the cave was determined by carbon dating. |
|  |  | 1. The Cave of Crystals (with larger crystals) is found at a shallower depth than the Cave of Swords (with smaller crystals). |
|  |  | 1. Visitors to the cave can stay for up to four hours. |
|  |  | 1. 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 your 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.*

1. **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.*

1. **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.*

1. **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 could too fast, the minerals would have been smaller as in the “Cave of Swords”*

1. **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.*

1. **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 or 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*

1. **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.*

1. **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.*

1. **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.*

1. **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 your 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**](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html) 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.