

**Teacher’s Guide**

**Tales of Concrete Forensics**

***December 2021***

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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_1)

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, the EdPuzzle, and a rubric to assess the graphic organizer.

[Additional Resources 10](#_Additional_Resources)

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. We use more concrete than any other construction material except water. |
|  |  | 1. Figuring out why concrete becomes damaged is often complex. |
|  |  | 1. Damage to concrete always creates a safety issue. |
|  |  | 1. Concrete detectives have backgrounds in geology, engineering, chemistry, and materials science. |
|  |  | 1. Concrete is a mixture of cement powder, sand, and gravel. |
|  |  | 1. The hardening of concrete is an endothermic reaction. |
|  |  | 1. As concrete sets, it expands. |
|  |  | 1. The manufacture of Portland cement releases CO2. |
|  |  | 1. Bacteria in sewage can cause damage to concrete if the sulfate in sewage is converted to sulfuric acid. |
|  |  | 1. Dissolved salt seeping into the pores of concrete strengthens concrete. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. Write out the chemical equation for the hydration of tricalcium silicate, as shown in the article, but on a single line.
2. The compound that is written after the arrow is one compound that contains three parts. The dots between each part signify that the three parts are bonded to each other in some way, acting as a single compound.
   1. According to its chemical formula, what is the mole ratio of calcium oxide to silicon dioxide to water in this new compound?
   2. How many moles of water are incorporated into each mole of the new compound?
   3. According to the chemical equation, how many moles of water are required to react with one mole of tricalcium silicate?
   4. Some of the water from the reactants is not accounted for in the hydrated (3-part) compound. Where did the rest of the water go?
   5. Math Challenge! A typical bag of cement weighs 42.6 kg. Tricalcium silicate composes 50% of the cement weight in a typical mix. Hydration of this compound is the primary process responsible for the first 7 days of curing. How much heat is absorbed or released in that first seven days, per bag of cement?
3. Explain why the extra water in the concrete mixture caused the Ohio warehouse floor to fail after only a few months of use.
4. Microbes in the Indiana wastewater treatment plant were noted as being the reason for the failure of an underground concrete holding tank.
   1. What role did the microbes play in this deterioration?
   2. Most people are familiar with the idea that acid can “eat away” materials and corrode them. This term is describing the fact that chemical reactions change the material in some way.
      1. Write a balanced chemical equation for the reaction of sulfuric acid with calcium hydroxide.

**Student Reading Comprehension Questions, cont.**

* + 1. Write a balanced chemical equation for the reaction of sulfuric acid with the calcium oxide portion of calcium silicate hydrate.
    2. Explain how the two reactions described above can weaken the structure of the concrete.

1. “Pesky powders” can sometimes be harmless and can sometimes be a sign of damage.
   1. What is efflorescence?
   2. From where do the water-soluble salts originate when efflorescence occurs?
   3. In efflorescence, how are the salts transferred to the surface of the concrete?
   4. Draw a particle-level model to represent sodium chloride dissolved in water. Show both the salt ions and the water molecules.
   5. Draw a particle-level model to represent sodium chloride after water has evaporated.
   6. When road salt splashes onto concrete it can leave a powdery residue similar to efflorescence, but it is not efflorescence. This, road salt can lead to cracking in the concrete. Referring to the particle models you drew in the previous two questions, explain why road salt causes cracking in concrete.

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. One concrete problem not discussed in the article is that it is a major contributor to global carbon dioxide emissions. Research the reaction(s) involved in this type of emission, record a chemical equation that describes the reaction, and identify three different ways that scientists and engineers are attempting to reduce these emissions.
2. People often confuse terms and use “cement”, “concrete”, and “mortar” interchangeably. Research these words and create a graphic organizer to compare and contrast the three materials.

# 

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe the problems with concrete in the following locations.

|  |  |  |
| --- | --- | --- |
| **Location** | **Cause of the Problem** | **Solution** |
| **Tiffin, Ohio warehouse** |  |  |
| **Springfield, Indiana wastewater treatment plant** |  |  |
| **Saint Charles, Virginia office building** |  |  |
| **Lima, Ohio parking structure** |  |  |

**Summary:** On the back of this sheet, write three new things you learned about concrete.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric, & [EdPuzzle](https://edpuzzle.com/media/6192e4011ae0394171078b0a)

1. **Write out the chemical equation for the hydration of tricalcium silicate, as shown in the article, but on a single line.**

*2 Ca­3SiO5 + 7 H2O 🡪 3CaO·2SiO2·4H2O + 3 Ca(OH)2 + 173.6 kJ/mol*

1. **The compound that is written after the arrow is one compound that contains three parts. The dots between each part signify that the three parts are bonded to each other in some way, acting as a single compound.**
   1. **According to its chemical formula, what is the mole ratio of calcium oxide to silicon dioxide to water in this new compound?**

***3****CaO·****2****SiO2·****4****H2O mole ratio is 3:2:4*

* 1. **How many moles of water are incorporated into each mole of the new compound?**

*3CaO·2SiO2·****4H2O***  *4 moles of H2O (one mole of the compound contains 3 moles of CaO, 2 moles of SiO2 and 4 moles of H2O)*

* 1. **According to the chemical equation, how many moles of water are required to react with one mole of tricalcium silicate?**

*2 Ca­3SiO5 +* ***7 H2O*** *🡪 3CaO·2SiO2·4H2O + 3 Ca(OH)2 + 173.6 kJ/mol*

*3.5 moles of H2O react with every mole of Ca­3SiO5.*

* 1. **Some of the water from the reactants is not accounted for in the hydrated (3-part) compound. Where did the rest of the water go?**

*4 of the 7 moles of H2O are incorporated into the hydrate. The others are incorporated into the other product, to make the hydroxides of Ca(OH)3.*

* 1. **Math Challenge! A typical bag of cement weighs 42.6 kg. Tricalcium silicate composes 50% of the cement weight in a typical mix. Hydration of this compound is the primary process responsible for the first 7 days of curing. How much heat is absorbed or released in that first seven days, per bag of cement?**

***2 Ca­3SiO5*** *+ 7 H2O 🡪 3CaO·2SiO2·4H2O + 3 Ca(OH)2* ***+ 173.6 kJ/mol***

*50% of 42.6 kg = 21.3 kg 🡪 21300 g*

*Molar mass of Ca­3SiO5 is 228.32 g/mol, so this is 93.3 moles of tricalcium silicate.*

*173.6 kJ of heat are released for every 2 moles of tricalcium silicate.*

*93.3/2\*173.6=****8.10 x 103 kJ b released***

1. **Explain why the extra water in the concrete mixture caused the Ohio warehouse floor to fail after only a few months of use.**

*The extra water made the cement paste too runny, so it wasn’t dense enough to keep the aggregates suspended. The aggregates, which are the components that makes the concrete durable, all sunk to the bottom, leaving the top few inches free of aggregates. This made the top portion of the floor much less durable, leading to cracking and flaking.*

1. **Microbes in the Indiana wastewater treatment plant were noted as being the reason for the failure of an underground concrete holding tank.**
   1. **What role did the microbes play in this deterioration?**

*The microbes (bacteria) converted the sulfates from the concrete into hydrogen sulfide, which turns to sulfuric acid when exposed to moist air. The sulfuric acid reacts with the components of concrete, thus deteriorating it.*

* 1. **Most people are familiar with the idea that acid can “eat away” materials and corrode them. This term is describing the fact that chemical reactions change the material in some way.** 
     1. **Write a balanced chemical equation for the reaction of sulfuric acid with calcium hydroxide.**

*H2SO4 + Ca(OH)2 🡪 2H2O + CaSO4*

* + 1. **Write a balanced chemical equation for the reaction of sulfuric acid with the calcium oxide portion of calcium silicate hydrate.**

*H2SO4 + CaO 🡪 H2O + CaSO4*

* + 1. **Explain how the two reactions described above can weaken the structure of the concrete.**

*Both reactions change a component of concrete that is part of its rigid structure. By changing these components, the internal structure is broken down, thus weakening the concrete.*

1. “**Pesky powders” can sometimes be harmless and can sometimes be a sign of damage.**
   1. **What is efflorescence?**

*Efflorescence is a deposit of salts that is left on a surface after the water that carried it has evaporated.*

* 1. **From where do the water-soluble salts originate when efflorescence occurs?**

*The salts in this case originate inside the concrete. They are already dissolved in water inside the concrete.*

* 1. **In efflorescence, how are the salts transferred to the surface of the concrete?**

*As the concrete continually cures over time, water that was previously bonded in the structure gets released and makes its way to the surface of the concrete, eventually evaporating. Salts that are not chemically bound within the structure can be dissolved along the way, thus left on the surface when the water evaporates.*

* 1. **Draw a particle-level model to represent sodium chloride dissolved in water. Show both the salt ions and the water molecules.**

Background pattern

Description automatically generated with medium confidence (*from* [*https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-7-solutions/*](https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-7-solutions/) *)*

* 1. **Draw a particle-level model to represent sodium chloride after water has evaporated**.

Background pattern

Description automatically generated with medium confidence(*from* [*https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-7-solutions/*](https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-7-solutions/) *)*

* 1. **When road salt splashes onto concrete it can leave a powdery residue similar to efflorescence, but it is not efflorescence. This, road salt can lead to cracking in the concrete. Referring to the particle models you drew in the previous two questions, explain why road salt causes cracking in concrete.**

*Since the salt from the road was not originally a part of the concrete, any salt water that makes its way into the structure can cause cracking as the water evaporates, leaving the crystallized salt in the pores, putting pressure on the pores making them turn into cracks.*

**Questions for Further Learning**

1. **One concrete problem not discussed in the article is that it is a major contributor to global carbon dioxide emissions. Research the reaction(s) involved in this type of emission, record a chemical equation that describes the reaction, and identify three different ways that scientists and engineers are attempting to reduce these emissions.**

*CaCO3 🡪 CaO + CO2*

*Answers may vary*

1. **People often confuse terms and use “cement”, “concrete”, and “mortar” interchangeably. Research these words and create a graphic organizer to compare and contrast the three materials.**

*Cement is made of limestone, clay, shells, and silica sand. It sets and hardens when combined with water.*

*Concrete is made of cement, sand, and gravel.*

*Mortar is made of cement and sand. It is used as glue to hold bricks and blocks together.*

*Graphic organizers may 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.

|  |  |  |
| --- | --- | --- |
| **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 |

[**EdPuzzle**](https://edpuzzle.com/media/6192e4011ae0394171078b0a) **Answers**

1. **Explain what is meant by the term "hydration."**

*Answers may vary but may include something along the lines of this: This is a chemical reaction when a substance mixes with water. Concrete consisting of aggregates hardens when water is added through hydration.*

1. **Why does it take a while for the concrete to gain strength?**

*It needs time for the water to make bonds*

1. **What is the significance of the little concrete character drinking a glass of water?**

*Answers may vary but may resemble something like this: It represents concrete’s natural self-healing mechanism.*

1. **Water hydrates the calcium oxide into calcium hydroxide. Write a chemical equation for the process described when calcium hydroxide reacts with carbon dioxide**.

*Ca(OH)2 + CO2 🡪 CaCO3 + H2O*

1. **Why don't the microbes die inside the concrete?**

*Some types of microbes can form a protective spore and become inactive until there are nutrients available for them.*

# Additional Resources

**Lessons and lesson plans**

**So, You Think Concrete Dries Out? Lesson:** Students will learn about the hydration process by creating samples of concrete and weighing them before and after the hydration process.

<https://www.cement.org/learn/education/concrete-in-the-classroom-(grades-7-12)/lesson-5-so-you-think-concrete-dries-out->

**Chemistry of Cement**: In this Activity, students use a commercially prepared cement mix to investigate the factors involved in the hardening of cement into concrete. Students manipulate variables such as concentration, curing temperature, and additions to the mixture, as well as testing the products for strength or hardness.

<https://pubs.acs.org/doi/abs/10.1021/ed083p1472A>

**Making Concrete**: Students will test to see how varying proportions of cement, water, and different aggregates affect the properties of their concrete mixtures. Using the scientific method, they can theorize which mixture will increase the stability and strength of their concrete mixture.

<https://edu.rsc.org/resources/making-concrete/2022.article>

**What if cracks in concrete could fix themselves? Edpuzzle**: Students can watch a video and answer questions on how concrete is prone to catastrophic cracking that has immense financial and environmental impacts and how scientists are trying to overcome these issues.

<https://edpuzzle.com/media/6192e4011ae0394171078b0a>

**Other Resources/Possible Extension Activities**

**Ask Nature Search:** Have students explore several interesting innovations of concrete inspired by nature <https://asknature.org/?s=concrete&page=0&is_v=1>

**Have students research different ways that scientists and engineers are making concrete “greener.”** Some examples are:

**Alternative materials could shrink concrete’s giant carbon footprint:**

<https://cen.acs.org/materials/inorganic-chemistry/Alternative-materials-shrink-concretes-giant/98/i45>

**Building’s hard problem- making concrete green:** <https://www.bbc.com/news/business-56716859>

**Eco-Friendly Alternatives to Traditional Concrete**: <https://www.specifyconcrete.org/blog/eco-friendly-alternatives-to-traditional-concrete>

**Is Greener Concrete the Key to Sustainable Construction?:** <https://www.constructconnect.com/blog/greener-concrete-key-sustainable-construction>

**The material could change the world… for a third time:** <https://youtu.be/hRI0ymx_6aw>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Chemical change
* Physical properties
* Mixtures

**Correlations to Next Generation Science Standards**

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

|  |
| --- |
| **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:**

* ETS1.B: Developing possible solutions

**Crosscutting Concepts:**

* Cause and effect
* Systems and system models

**Science and Engineering Practices:**

* Analyzing and interpreting data
* Constructing explanations and designing solutions

**Nature of Science:**

* Scientific knowledge is based on empirical evidence.

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).

**Teaching Strategies**

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

* **Alternative to Anticipation Guide:** Before reading, ask students what they know about concrete, how it is made, and problems with concrete structures. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
  + As they read, students can find information to confirm or refute their original ideas.
  + After they read, ask students what they learned about carbon dioxide.
* After students have read and discussed the article, consider showing the ACS Reactions Video “Science of Concrete and the Surfside Condo Collapse” at <https://youtu.be/4Nr3w1BQE18> to learn more about the science of concrete and what may have happened at the Surfside Condo.