# The Effects of Mineral Dissolution on Water Quality

**Skill Level**
High School
Earth Science,
Chemistry, or
Environmental Science

**Learner Outcomes**
- Understanding the concept of pH
- Understanding that the dissolution of minerals affects water quality
- Understanding that the dissolution of some minerals can be beneficial for water treatment

**Success Indicators**
- Students can discuss what pH is.
- Students can discuss the effects of mineral dissolution on water quality.
- Students can articulate how minerals can be used to protect and treat water.

**Life Skill(s)**
Critical Thinking
Problem Solving
Learning to Learn
Record Keeping

**Tags**
Earth science, geology, rocks, minerals, water, quality, pH

**Time Needed**
30-40 minutes

**Materials List**
Crushed calcite*
Crushed pyrite*
pH strips with color scale*
Water
Small vials with caps*
Plastic beakers or graduated cylinders
Paper towels
Timer or stopwatch
Worksheets (see end of activity)

**Available upon request from Madeline Schreiber (mschreib@vt.edu)*

As an essential component of all forms of life, clean water is necessary for humans, animals, and plants. Water interacts with minerals in rocks, which can change the chemistry of the water. Minerals can dissolve in water, meaning that they can completely mix with water (think of table salt dissolving in water). Some minerals dissolve quickly, over hours to days to months to years, while others dissolve much more slowly, over hundreds of thousands of years or longer. Minerals contain elements that can be both beneficial for human health (e.g., calcium, magnesium, iron) but also harmful to human health (e.g., arsenic, mercury, lead). Thus, when water interacts with minerals for long periods of time, many different elements can be released to the water that can affect the water quality, which is defined by the U.S. Geological Survey (https://www.usgs.gov/special-topics/water-science-school/science/water-quality-information-topic) as the suitability of water for a particular use based on selected physical, chemical, and biological characteristics.

The effect of mineral dissolution on water quality is particularly important for groundwater (water that occupies pores and open spaces in soils and rocks in the subsurface) That's because groundwater can interact with minerals in the subsurface for long periods of time (in some places, more than a million years!). Because groundwater provides drinking water to 50% of the world's population (www.groundwater.org), understanding how mineral dissolution affects groundwater quality is important for protection of human and health.

Pyrite and calcite are two minerals commonly found in rocks. Pyrite ($FeS_2$), also called "fool's gold," is a mineral that contains both iron and sulfur (fig. 1, left). Calcite ($CaCO_3$) (fig. 1, right) makes up limestone, a common sedimentary rock that is often used for road and building material.

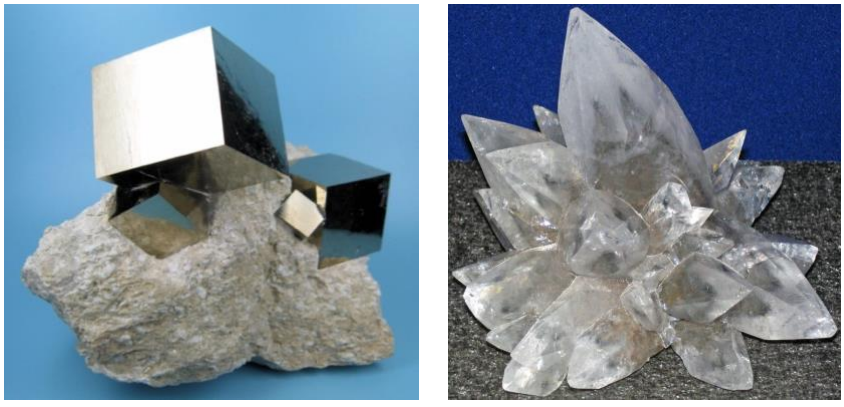

Figure 1. Pyrite (left) and calcite (right). (Photos from the Smithsonian Collection.)

**Structured Inquiry**
Leader Centered

Virginia Cooperative Extension
Virginia Tech • Virginia State University

This project was sponsored by
Freshwater Systems Destination Area of Virginia Tech

When pyrite and calcite dissolve in water, they change the pH of the water. pH is the measure of concentration of protons ($H^+$) in solution. It reflects how acidic or basic a solution is. Solutions that are acidic have a low pH (<7); solutions that are basic have a higher pH (>7) (fig. 2). Water is often assumed to have a neutral (~7) pH, but it is actually a bit lower (5.5-6) due to dissolution of carbon dioxide ($CO_2$) from the atmosphere.

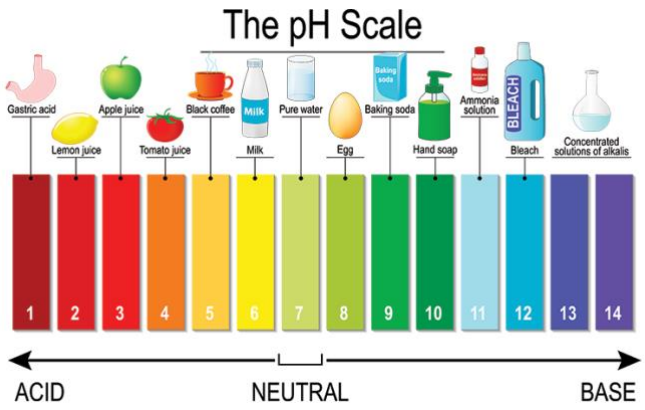


Figure 2. Ranges of pH for common fluids (https://www.sciencenewsforstudents.org/).

The dissolution of pyrite and calcite can also change the pH of water. Pyrite dissolves through a process called oxidation. In oxidation, the sulfur in pyrite is oxidized (loses electrons). This is coupled with a reduction of oxygen while oxygen is reduced (gains electrons). The reaction produces sulfuric acid ($H_2SO_4$), which is a strong acid.

$$FeS_2 + \frac{15}{4}O_2 + \frac{7}{2}H_2O = Fe(OH)_3 + 2H^+ + {SO_4}^{2-}$$

Dissolution of pyrite in the environment, associated with areas of coal mining and metal mining, can produce acid rock drainage, which has low pH (see reaction earlier) and can also have high concentrations of metals such as iron (see fig. 3).

Figure 3. Acid rock drainage. Reprinted from “Mine Drainage, “U.S. Geological Survey. (https://www.usgs.gov/mission-areas/water-resources/science/mine-drainage.)



This project was sponsored by
Freshwater Systems Destination Area of Virginia Tech

In contrast to pyrite, as calcite dissolves, it consumes protons ($H^+$), which increases pH.

$$CaCO_3 + H^+ = Ca^{2+} + HCO_3^-$$

The reaction of calcite (or limestone, the rock that is formed from calcite) with acid rock drainage results in neutralization of the acid.

## Term and Concept Introduction

pH – the measure of the concentration of protons ($H^+$) in solution.

Acidic – solutions with pH < 7

Basic – solutions with pH > 7

Neutral – solutions with pH about 7

Mineral weathering – the process of chemical and physical breakdown (dissolution) of minerals

Calcite – mineral with formula $CaCO_3$

Pyrite – mineral with formula $FeS_2$

Limestone – rock made up of $CaCO_3$

Acid rock drainage – acidic water resulting from weathering of pyrite and other sulfide minerals.

## Supplies Needed

- Distilled or deionized water in a squirt bottle (tap water is OK)
- Plastic graduated cylinder or beaker (to measure 10 milliliters of water)
- 0.5 to 1 grams crushed calcite*
- 0.5 to 1 grams crushed pyrite*
- Small vials with caps*
- pH strips (0-14 OK; if have separate strips for 0-6 and 5-9, you can use the 0-6 for pyrite and 5-9 for calcite)
- Worksheets (or paper) to record data
- Timer or stopwatch
- Paper towels

*Supplies available upon request from Dr. Madeline Schreiber (mschreib@vt.edu)



This project was sponsored by
Freshwater Systems Destination Area of Virginia Tech

## Facilitator Notes and Preparation

- Have vials of crushed pyrite and calcite and other supplies ready and placed on lab table, along with the other supplies listed above.
- Break students into pairs or groups based on the amount of availability of supplies and space.
- There are accompanying slides to facilitate the activity.
- There are three parts of the activity. Break after each activity to check in with students and ask questions.
- After Part 2, use the slides to ask students the following questions:
    a. What were your expectations for the pH of calcite-water and pyrite-mixture? (See pre-activity questions.)
    b. Why did you expect this? (Refer students back to the pyrite dissolution and calcite dissolution equations. Which one produces protons, which would create acidic conditions, and which one consumes protons, which would help neutralize acidity?)
- In preparation for Part 3, use the slides to ask students what they expect to happen to the pH if they mix the calcite and pyrite (and water) together.
- After Part 3, make a table on the board, where one group member records their data on the board to share results for all three activities.
- After results are put in the table, ask students again what their expectations were for the pH of calcite-water and pyrite-mixture, and if the results supported those expectations.
- After results are discussed, present slides on water treatment and use of limestone to treat acid rock drainage. There is a video on this process embedded in the slides that could be shown in full or in part.
- Recap: What did we learn? Refer to questions under "Share/Process/Generalize" and "Apply" headings that follow.

## Opening Questions

- Do you know where your water at home comes from? From a well? From a river? From a drinking water reservoir?
- Do you know what types of rocks underlie your area? If not, look at the geologic map of your state (check the U.S. Geological Survey website (https://www.usgs.gov/products/maps/geologic-maps).

## Activity

In this activity, we're going to dissolve pyrite and calcite in water and measure the pH after the minerals dissolve. This activity is best for pairs of students or groups of three or four students. Students will need to decide who does the experiment and who records the data.

## Pre-Activity Questions

- Do you think the pH of water will increase or decrease when it interacts with **calcite**?
- Do you think the pH of water will increase or decrease when it interacts with **pyrite**?

## Facilitated Activity (Three parts)

- **Activity Part 1: Calcite dissolution**
    1. Measure 10 milliliters of water in a graduated cylinder or beaker.
    2. Dip pH strip (use a 0-6 pH strip) into water.
    3. Wait 30 seconds, then match color to pH color scale to find pH.
    4. This is the initial pH; record in Tables 1, 2, and 3 below.
    5. Pour water into vial with calcite. Put cap on.
    6. Start timer and shake for 2 minutes.
    7. Let sit for 30 seconds or so.
    8. Measure pH with a 5-9 pH strip.
    9. Wait 30 seconds, then match the strip color to the pH color scale.
    10. Record measurement in Table 1, which follows.

- **Activity Part 2: Pyrite dissolution**
    1. Measure 10 ml of water in a graduated cylinder or beaker.
    2. Pour water into the vial labeled pyrite. Put cap on.
    3. Start timer and shake for 2 minutes.
    4. After 2 minutes, let sit for 30 seconds or so.
    5. Measure pH with a 0-6 pH strip.
    6. Wait 30 seconds, then match the strip color to the pH color scale.
    7. Record measurement in Table 2, which follows.

- **Activity Part 3: Pyrite- calcite reaction**
    1. Give your calcite-water mixture a quick shake.
    2. Pour the calcite-water mixture into the vial with pyrite-water mixture.
    3. Shake the pyrite - calcite mixture for 2 minutes.
    4. Let sit for 30 seconds or so.
    5. Measure pH with 0-6 pH strip.
    6. Wait 30 seconds before matching to the pH color scale.
    7. Record pH in Table 3, which follows.
    8. Compare to the pyrite pH measurement from Table 2.

## Share/Process/Generalize

- Did your experimental results meet your expectation for the mixture of calcite and pyrite together?
- Why do you think that happened?

## Apply

- In addition to the examples that were shown in the slides, how else do you think minerals can be used to improve water quality?
- Discuss the example of limestone treatment of acid rock drainage treatment (see slides and embedded video).
- Can you think of examples in which mineral dissolution in water will make water harmful – or even deadly – to fish or other animals, including humans?

# References

"Acid Mine Drainage Treatment." PBS LearningMedia,Video, 7:00 minutes long (can use portion of video). (https://www.pbslearningmedia.org/resource/watsol.sci.ess.water.amdren/acid-mine-drainage-remediation/)

"Maps." U.S. Geological Survey, accessed October 4, 2023. https://www.usgs.gov/products/maps/geologic-maps

# Resources

Please contact Dr. Madeline Schreiber (mschreib@vt.edu) for mineral kits. Kits include crushed calcite and pyrite, and pH strips with color scale for measurements.

# Authors

Wynnie Avent, Madeline Schreiber, Erika Bonnett, and Erin Ling (Virginia Tech)

# Supplemental Information

See Power Point slides for additional information and guidance
Worksheet for pH measurements below.



Virginia Cooperative Extension
Virginia Tech • Virginia State University

This project was sponsored by
Freshwater Systems Destination Area of Virginia Tech

# Worksheet for the Effects of Mineral Dissolution on Water Quality

## Part 1. React calcite with water

1. Measure 10 milliliters of water in a graduated cylinder or beaker.
2. Dip pH strip (use a **0-6 pH strip**) into water.
3. Wait 30 seconds, match color to pH color scale to find pH.
4. This is the **initial pH**; record in Tables 1, 2 and 3, which follow.
5. Pour water into vial with **calcite**. Put cap on.
6. Start timer and shake for 2 minutes.
7. Let sit for 30 seconds or so.
8. Measure pH with a **5-9 pH strip.**
9. Wait 30 seconds, then match the strip color to the pH color scale.
10. Record measurement in Table 1, below.

### Table 1. pH of water after reacting with calcite

| Stage of pH | pH |
|---|---|
| Initial pH of water (use 0-6 pH strip) | |
| pH of water after reaction with calcite (use 5-9 pH strip) | |

## Part 2: React pyrite with water

1. Measure 10 milliliters of water in a graduated cylinder or beaker.
2. Pour water to the vial labeled **pyrite.** Put cap on.
3. Start timer and shake for 2 minutes.
4. After 2 min, let sit for 30 seconds or so.
5. Measure pH with a **0-6 pH strip.**
6. Wait 30 seconds, then match the strip color to the pH color scale.
7. Record measurement in Table 2, below.

### Table 2. pH of water after reacting with pyrite

| Stage of pH | pH |
|---|---|
| Initial pH of water (from Table 1, don't need to re-measure) | |
| pH of water after reacting with pyrite (use 0-6 pH strip) | |



This project was sponsored by
Freshwater Systems Destination Area of Virginia Tech

**Part 3: React calcite and pyrite mixtures together**

1. Give your calcite-water mixture a quick shake.
2. Pour the calcite-water mixture into the vial with pyrite-water mixture.
3. Shake the pyrite - calcite mixture for 2 minutes.
4. Let sit for 30 seconds or so.
5. Measure pH with **0-6 pH strip.**
6. Wait 30 seconds before matching to the pH color scale.
7. Record pH in Table 3 below.
8. Compare to the pyrite pH measurement from Table 2.

**Table 3. pH of calcite-pyrite mixture**

| Stage of pH | pH |
|---|---|
| Initial pH of water (from Table 1, don't need to re-measure) | |
| pH after reacting with calcite **and** pyrite (use 0-6 pH strip) | |

Visit our website: www.ext.vt.edu
Produced by Virginia Cooperative Extension, Virginia Tech, 2023



VT/1123/4H-1024P