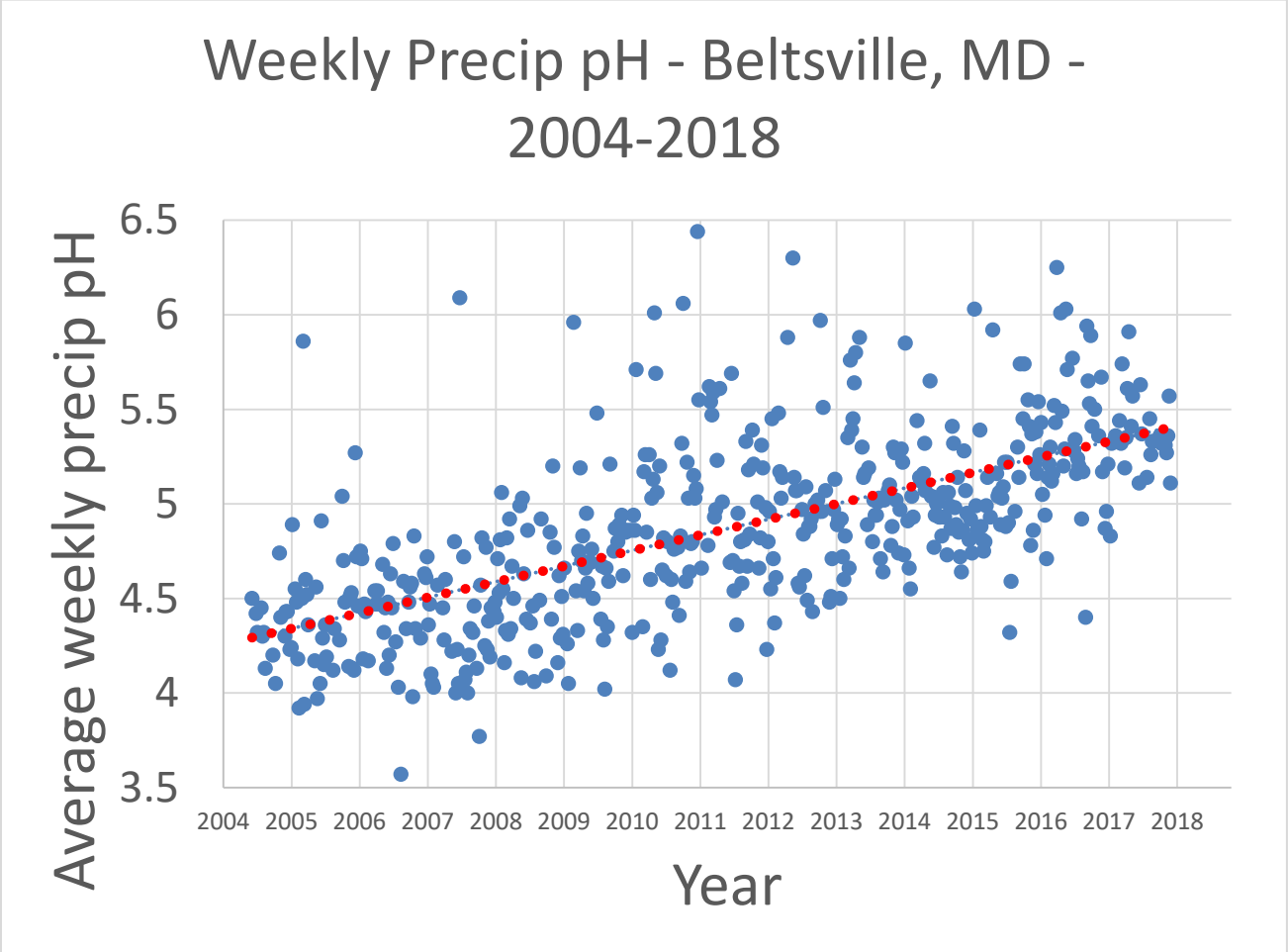
Integrating Chemistry & Earth Science

**WEATHERING, EROSION & DEPOSITION MODULE**

# LESSON 3:

# CHEMICAL WEATHERING




THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

BALTIMORE CITY PUBLIC SCHOOLS

NSF

Cary Institute of Ecosystem Studies

# ACKNOWLEDGEMENTS

**ICE Leadership Team**

- Alan R. Berkowitz, Head of Education, Cary Institute
- Joshua Gabrielse, Director of Science, City Schools
- Kevin Garner, Coordinator of Science, City Schools
- Kia Boose, Secondary Science Specialist, City Schools
- Vonceil Anderson, Curriculum Writer, City Schools
- Jonathon Grooms, Assistant Professor of Curriculum and Pedagogy, George Washington University
- Kevin Fleming, Graduate Research Assistant, George Washington University
- Mary Ellen Wolfinger, Doctoral Student, George Washington University
- Bess Caplan, Ecology Education Program Leader, Baltimore Ecosystem Study
- Tanaira Cullens, Education Assistant, Baltimore Ecosystem Study
- Chelsea McClure, Education Assistant, Baltimore Ecosystem Study
- Martin Schmidt, Upper School Science, McDonogh School

The following lesson and associated materials are part of the Integrating Chemistry and Earth science (ICE) Urban Heat Island Module. The Module brings together important concepts from Earth science and chemistry to help students build an understanding of why urban areas have higher temperatures both during the day and at night, than their rural counterparts.

## ICE Partners

Cary Institute of Ecosystem Studies

BALTIMORE CITY PUBLIC SCHOOLS

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

*This material is based upon work supported by the National Science Foundation under Grant* #DRL-1721163*. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

ICE Integrating Chemistry & Earth Science

# Lesson 3: Chemical Weathering

**Driving Question:** *How do chemical processes break down mountains?*

**Summary:** Students should have an idea of the following: Physical weathering breaks objects into smaller pieces but does not change the identity of the object. Water is a major component of Physical weathering due to its ability to expand when it freezes and through flowing water aiding in abrasion. These two processes are a significant component in the formation of potholes in city streets as well as the natural landscape. Questions they should consider include: how can weathering change the composition of the rocks?

**Activity Description:**

- **Opening Activity:** Engage students' prior understandings of the idea of acid rain with this opening discussion/brainstorming session and its connections to weathering. Remember, chemical weathering involves chemical changes in physical materials (rocks, etc.) due to interactions with water and/or acids, or oxidation.
    - Ask students to recall what they know about acid rain.
        - How does it form?
        - Why are we concerned about acid rain?
        - What are the impacts of acid rain, particularly in urban areas?
    - Students share what/where they should look to determine how much acid rain is affecting Baltimore.
    - Pass out sticky-notes and have students write their estimate of the average pH of rain in Baltimore. Post to the board.
        - **Teacher Note:** Draw a pH scale on the board and have students put their sticky-notes on the scale where they think the pH of acid rain would be.
    - Share the highest and lowest estimates.
- **Analyzing Rain Data:** In this investigation students will analyze Maryland rain data to determine pH trends.
    - Students will determine both the average pH and the pH range of rain in our region.
        - **Teacher Note:** This activity uses excel data. It may be completed with students at individual computers, or as a guided activity from one screen, or offline with data printouts.
    - Students complete the exercises and answer questions in the Precipitation Chemistry Data Worksheet.
        - Provide students with rain data from the *Precipitation chemistry NTN – Beltsville MD excel file* (see the graph on the 3rd tab) from the National Acid Deposition Program (NADP) site in Beltsville, MD.
        - Students determine both the range and average pH of rain in our region.
        - Ask students to raise their hands if their estimates of the average rain pH were

correct.
    - Ask students to raise their hands if their estimates fell within the range of typical acid rains.
    - Ask students to determine what reactions could occur if acidic rainwater falls on concrete in Baltimore.
        - How will that change the pH of the water running into our storm drains and streams?
        - Consider what you learned about local rain pH in designing and interpreting the study.

- **Chemical Weathering Lab** (Read the Teacher Instructions for more information): Students will develop their own research protocols for this investigation on how acid rain (simulated by vinegar) effects local rocks (simulated by chalk). Students choose their own variables and data collection methods before beginning the activity.
    - Divide students up into groups of no more than three students.
    - Hand out the Lab investigation Proposal worksheet to each group.
    - Students use the Lab Investigation Proposal worksheet to design an investigation based on the guiding question, "What determines how much rocks are affected by acid rain?" Be sure to sign off on their protocol before allowing each group to begin their investigation.
        - Available materials include:
            - balances
            - LabQuests
            - pH sensors
            - vinegar (acetic acid)
            - water
            - chalk (a soft sedimentary rock)
            - granite rock samples
    - Students must complete all but "The Actual Results" box before they get the instructor sign-off and receive their materials.
        - Their plan should include safety measures.
    - Students carry out their investigation and record their data on the lab worksheet and their results in "The Actual Results" box of the Laboratory Investigation Proposal A.
    - Students analyze their data and construct an explanation.
    - Students should share what they learned with the other groups.

**Homework:** Pass out the *CER Graphic Organizer* worksheet. Students respond individually to their guiding question (What determines how much rocks are affected by acid rain?) with a written argument including:

- a claim.
- a description of the supporting evidence from their investigation.

- and an explanation of their reasoning.

**EL Support:** Purposefully choose one or more of the following options based upon student needs or formative assessment data to have students process and engage with content.

- Modify classwork, assessments, homework (true/false, reduced responses)
- Provide written notes
- Provide visuals
- Clarify or provide directions in the native language

**Differentiated Instruction:** Purposefully choose one or more of the following options based upon student needs or formative assessment data to have students process and engage with content.

- Even though students are designing their own lab, be prepared to give explicit instructions to support students who need more structure. These can include guidelines for how the procedures should be written, specific components that must be present, peer/teacher review of procedures, requirements for stated safety procedures, etc.

For students who need support with writing their CER, provide *CER Graphic Organizer.* Students can also color code their writing, having a different color for each component in the Claim Evidence Reasoning format.

**Lesson Summary:** Students should have an idea of the following: Chemical weathering changes the chemical composition of the matter being weathered. This can happen through dissolution by water or by chemical reactions. Oxidation processes, such as rusting are classified as chemical weathering. Chemical reactions with acids, such as those found in acid rain and other water sources and those produced by living organisms, also are factors in chemical weathering. Students should be wondering where the weathered materials, both chemical and physical, go once broken down from the original rock.

# Precipitation Chemistry Data Worksheet

**Overview:**

Beltsville, MD is the closest location to Baltimore, MD where rainfall chemistry is measured on a regular basis. This site is part of the National Trends Network (NTN), which in turn is part of the National Atmospheric Deposition Program (NADP). You can learn more about this program at: http://nadp.slh.wisc.edu/ntn/. Data is available for the 4 year period between 2014 and almost the end of 2017 for several variables, including pH, conductivity, several anions and cations, and precipitation amount.

Your exploration should help you address questions such as:

1. Is the precipitation in Baltimore (i.e., Beltsville) acidic?
2. What constituents in the rain correlate with pH?
3. How has it changed over time?
4. How can you explain any changes you see over time?

You have three options for exploring these data:

A. Directly on the website
B. Using the excel file provided
C. Considering the graphs in the powerpoint provided

Instructions for each follow.

**A. Web exploration of data**

1. Go directly to: http://nadp.slh.wisc.edu/data/sites/siteDetails.aspx?net=NTN&id=MD99

2. Choose the Trend Plots option. This automatically shows annual averages of precipitation pH over time. Years where they didn't have what they call the "annual criteria" met are in red and are excluded from the continuous trendline.

   Is there a pattern of pH over the years and if so, what is the pattern?

3. Use the "What to Plot" options just below the graph to choose different parameters to see how they change over time. Use this to explore what precipitation constituents correlate with the pattern of pH you observed.

   What constituents correlate best with the pattern of precipitation pH? Why do you think this is the case?

**B. Excel file**

1. Open the excel file, Precip chemistry (NTN) – Beltsville MD

2. Get to know the data by reviewing the worksheets, About the data and All data – with pH only. You will see weekly data (for those weeks where pH data was recorded) from 2004 to 2017 for a number of variables described in the About the data worksheet.

3. To get an idea of the range, variability and central tendency (mean, median) of the pH data for the most recent year, look at the 2017 data- box and whisker graph.

   What are the mean (x) and range of the data, and what are the outliers?

4. Decide on how you want to look for pH trends over time and make the appropriate graphs. Alternatively, look at the graph, Weekly Precip pH – 2004-2018. This includes a trendline fit by excel to the data. The $R^2$ of .4172 indicates that just under 42% of the variation in pH is explained by the trendline over years.

   What is the trend in precipitation pH over time? How can you explain this trend? Why might there be so much variability within any given year?

5. Consider what constituents in the precipitation correlate best with the pH. Use data in the All data – pH only worksheet to explore possible relationships.

   What factors did you find that best correlate with precipitation pH? Why do you think this was the case? Were you able to eliminate other factors?

**C. Graphs in powerpoint file**

1. Open the powerpoint file, Precip chemistry (NTN) – Beltsville MD graphs.

2. To get an idea of the range, variability and central tendency (mean, median) of the pH data for the most recent year by looking at the 2017 data- box and whisker graph (1st slide).

   What are the mean (x) and range of the data, and what are the outliers?

3. Look at the graph, Weekly Precip pH – 2004-2018 (second slide). This includes a trendline fit by excel to the data. The $R^2$ of .4172 indicates that just under 42% of the variation in pH is explained by the trendline over years.

   What is the trend in precipitation pH over time? How can you explain this trend? Why might there be so much variability within any given year?

# Chemical Weathering—Teacher Instructions

*Purpose/Objectives:*

- Students design and carry out an investigation using chalk and vinegar to mimic what happens when acid rain falls on concrete.

*Agenda:*

| ***Activity #*** | ***Activity Label*** | ***Timing*** | ***Activity Description*** |
|---|---|---|---|
| 1 | Design | 20 | Students design an investigation examining how and why vinegar dissolves chalk. |
| 2 | Experiment | 20 | Students carry out their investigation examining how and why vinegar dissolves chalk. |
| 3 | Constructing Explanations | 10 | Students use evidence and reasoning from their investigation to support a claim. |

*Materials Needed:*

- Vernier LabQuests
- Vernier pH meters
- Small plastic cups
- Chalk (a soft sedimentary rock)
- Vinegar (acetic acid)
- Balances
- Item to break chalk (ex: scissors or hammer)
- Laboratory Investigation Proposal worksheet
- Claims, Evidence, Reasoning Graphic Organizer
- Gloves, aprons, goggles

*Safety Concerns:*

Although students are familiar with household uses of vinegar, students should be instructed to follow safety protocols in the lab. Gloves, aprons and goggles should be worn at all times. Students should be instructed not to taste or smell the acid, even by wafting. Students should follow basic lab safety rules including tying back hair and wearing closed toe shoes in the lab.

*Activity 1: Design an investigation*

1. Students need to start by developing a question about the impact of acid rain that they can answer by modeling acid rain with the materials provided.
2. Ask students to consider the materials provide for the acid rain weathering lab
    a. Chalk is a soft sedimentary rock.
    b. Vinegar is an acetic acid solution.
3. Consider measurements you can take
    a. Observe substrate (can you do that quantitatively?)
    b. Change in water chemistry (pH)
4. Consider the chemical reaction(s) involved
5. Be sure to walk around the room and help students trouble shoot their investigative designs. Student investigations should only include materials that are available for the lab, should be short in nature and allow them to collect data.
6. Encourage students to think about the use of the scale in their investigation. Students can measure start and end weights of their cups with chalk and vinegar. Where did the lost weight go? CO2 was released to the atmosphere which caused the weight of the cup to go down. Students can compare large chunks of chalk with chalk dust (weight being equal) to see in which cup the pH goes up the most. In this case, surface area plays an important role. Or simply, students can see how the pH changes when chalk is added to the vinegar.

Activity 2: Conduct the investigation

7. Students should carry out their investigations.
8. Be sure students record their data.

Activity 3: Construct an explanation

9. Pass out the *CER Graphic Organizer*. Students work in their teams to complete the worksheet using data from their investigation.
10. Each group shares their results with the class.

Extension

- Class discussion on how this activity is related to Acid Rain
- What are the chemical formulas for vinegar and chalk. What is the chemical reaction taking place? $HC_2H_3O_2$ and $CaCO_3$, $2(HC_2H_3O_2) + CaCO_3 \rightarrow Ca(C_2H_3O_2)_2 + H_2O + CO_2$

# Chemical Weathering Lab - Acid Breakdown of Chalk

*Summary:*
Students learn about the impact of acid rain in an urban environment. Students design and carry out an investigation using chalk and vinegar to mimic what happens when acid rain falls on urban surfaces.

*Purpose/Objectives:*

- SWBT design and carry out an inquiry investigation using chalk and vinegar to mimic what happens when acid rain falls on urban surfaces.

*Agenda:*

| ***Activity #*** | ***Activity Label*** | ***Timing*** | ***Activity Description*** |
|---|---|---|---|
| 1 | Introduction to Activity | 10 | Students discuss the impacts of acid rain on Earth's materials including man-made construction materials. |
| 2 | Chalk/Vinegar Lab | 20 | Students design and carry out an investigation examining how and why vinegar dissolves chalk. |
| 3 | Claims, Evidence, Reasoning Share | 10 | Students use evidence and reasoning from their investigation to support a claim. Students share their results with the class. |

*Materials Needed:*

- Vernier LabQuests
- Vernier pH meters
- Small plastic cups
- White chalk
- Scales
- Item to break chalk (ex: scissors or hammer)
- Laboratory Investigation Proposal A worksheet
- Claims, Evidence, Reasoning Graphic Organizer
- Gloves, aprons, goggles

*Safety Concerns:*

Although students are familiar with household uses of vinegar, students should be instructed to follow safety protocols in the lab. Gloves, aprons and goggles should be worn at all times. Students should be instructed not to taste or smell the acid, even by wafting. Students should follow basic lab safety rules including tying back hair and wearing closed toe shoes in the lab.

Lesson Sequence:

*Activity 1*

1. Begin with a class discussion. If students have learned about acid rain, ask them to recall what they know about it. How does it form? Why are we concerned about acid rain? What are the impacts of acid rain, particularly in urban areas?
2. If students are unfamiliar with acid rain, describe the phenomenon and ask them to predict what might happen to Earth's surfaces (both natural and manmade) if enough acid rain fell? For more information on Acid Rain visit EPA's acid rain site.
3. Tell students they will design an investigation examining the impacts of an acid on chalk. Explain that chalk represents Earth's materials and we want to know what happens when these materials are exposed to an acid.
4. Pass out the Lab Investigation Proposal worksheet and group students appropriately.

*Activity 2*

11. Give students no more than 10 minutes to complete the Lab Investigation Proposal worksheet.
12. Start by asking students to develop a question about the impact of acid rain that you can answer by modeling acid rain with the materials provided.
13. Consider the materials provide for the acid rain weathering lab
    a. Substrate type and size
    b. Acid type and concentration (pH)
14. Consider measurements you can take
    a. Observe substrate (can you do that quantitatively?)
    b. Change in water chemistry (pH)
15. Consider the chemical reaction(s) involved
16. Be sure to walk around the room and help students trouble shoot their investigative designs. Student investigations should only include materials that are available for the lab, should be short in nature and allow them to collect data.
17. Encourage students to think about the use of the scale in their investigation. Students can measure start and end weights of their cups with chalk and vinegar. Where did the lost weight go? CO2 was released to the atmosphere which caused the weight of the

cup to go down. Students can compare large chunks of chalk with chalk dust (weight being equal) to see in which cup the pH goes up the most. In this case, surface area plays an important role. Or simply, students can see how the pH changes when chalk is added to the vinegar.

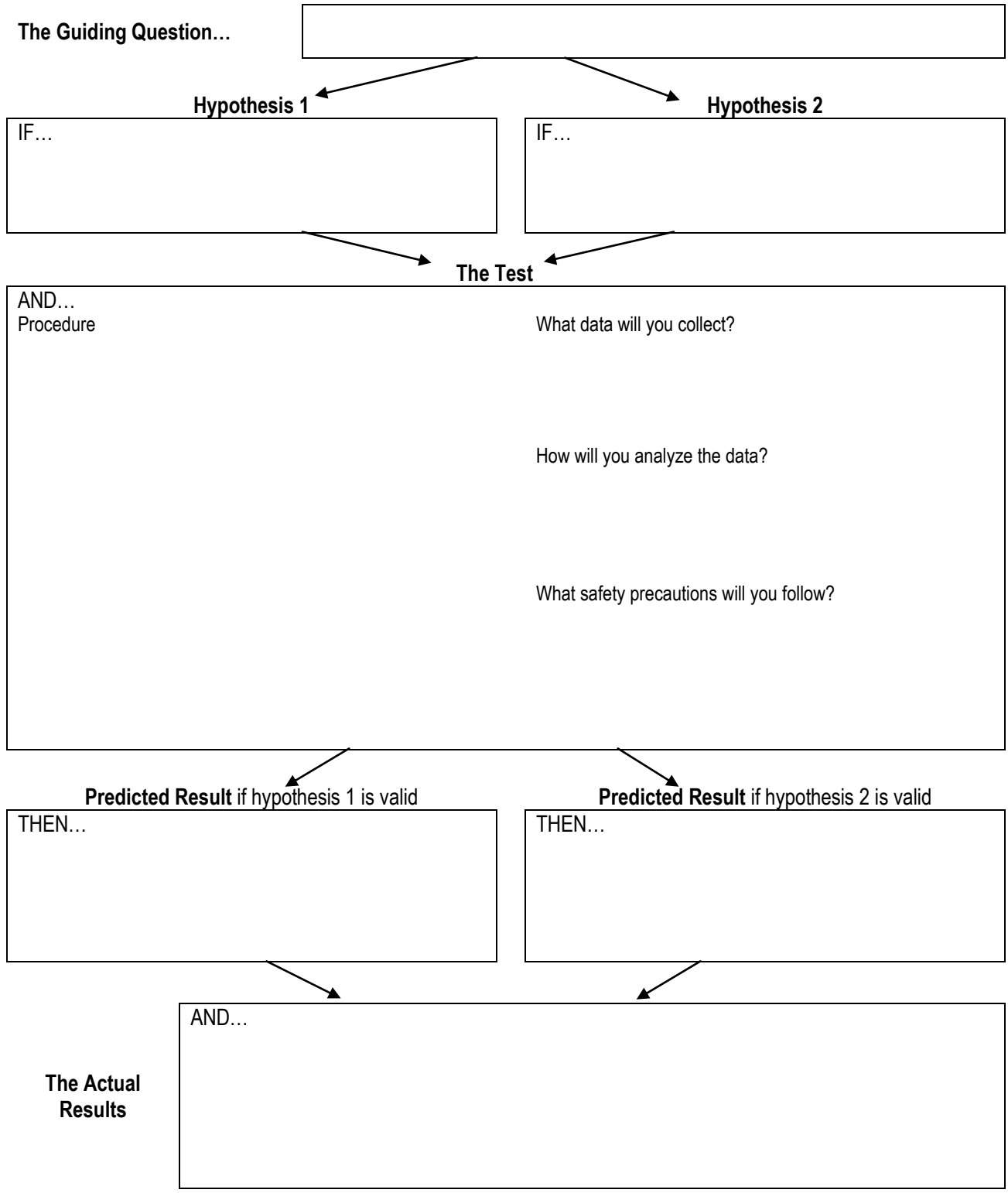
18. Students should carry out their investigations.
19. Be sure students record their data.

*Activity 3*

1. Pass out the *CER Graphic Organizer.* Students work in their teams to complete the worksheet using data from their investigation.
2. Each group shares their results with the class.

Extension

- Class discussion on how this activity is related to Acid Rain
- What are the chemical formulas for vinegar and chalk. What is the chemical reaction taking place? $HC_2H_3O_2$ and $CaCO_3$, $2(HC_2H_3O_2) + CaCO_3 \rightarrow Ca(C_2H_3O_2)_2 + H_2O + CO_2$




I approve of this investigation. _____ Instructor's Signature _____ Date