THE INTERNATIONAL EXHIBITION OF

SHERLOCK HOLMES

The Proof is in the Powder

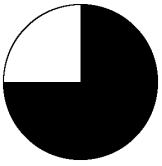
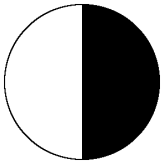
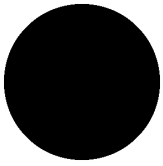
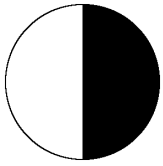
Pre-Exhibit Field Trip: Grades 3-5

In this activity, students will design a way to identify a powder found at a crime scene by comparing it with known powders, with the goal of solving a crime.

LEARNING OBJECTIVES

- Students will learn to describe the various physical properties of chemicals
- Students will understand the types of changes that can occur in a chemical reaction
- Students will learn to use deductive reasoning to solve problems

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
45 minutes	**30 minutes**	**50-60 minutes**	**30 minutes**

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large group discussion	5 min
Crime Scene Story	Instructor-led Activity	5 min
Powder Testing	Partner Activity	20-35 min
Wrap up	Large group discussion	10 min

SITE REQUIREMENTS

- Ideal to have access to a sink

NEXT GENERATION SCIENCE STANDARDS

Practices

1. Asking questions and defining problems
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

1. Patterns
2. Cause and effect
6. Structure and function
7. Stability and change

Disciplinary Core Ideas

	Grade Level:	3	4	5
Physical Science				
PS1	Matter and Its Interaction	n/a	n/a	✓
PS2	Motion and Stability: Forces and Interactions		n/a	
PS3	Energy	n/a		
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a
Life Science				
LS1	From Molecules to Organisms: Structures and Processes			
LS2	Ecosystems: Interactions, Energy, and Dynamics		n/a	
LS3	Heredity: Inheritance and Variation of Traits		n/a	n/a
LS4	Biological Evolution: Unity and Diversity		n/a	n/a
Earth & Space Science				
ESS1	Earth's Place in the Universe	n/a		
ESS2	Earth's Systems			
ESS3	Earth and Human Activity			
Engineering, Technology, and Applications of Science				
ETS1	Engineering Design			

Topics: Physical Change, Chemical Change, Chemistry, Acids, Bases, Inquiry

SUPPLIES

Notes on activity setup:
The supplies section and activity instructions assume your students will use five different tests to identify six different powders. For a shorter activity, you may choose to use fewer tests to identify fewer powders, or substitute different powders, while still using the Crime Scene Story. See the Advance Preparation on page 5 for suggestions on how to alter the activity.

There are also a variety of ways to alter the activity if you choose not to use the Crime Scene Story. To create an abbreviated or extended version of the activity, see the following pages:

- Use five tests to identify 12 powders (page 31)
- Use three tests to identify eight powders (page 32)
- Use two tests to identify five powders (page 33)
- Use two tests to identify six powders (page 33)

In addition, there are different ways that you can set up this activity. You can give each student group all of the powders they will test or you can set up "stations" with particular powders that students will rotate through.

If each student group has all the powders, the activity provides more substantial and meaningful experiences for each student but requires more preparation and a greater number of powders, plastic cups, spoons, etc. Student stations are easier to set up and require fewer materials, but require more management as students rotate.

Permanent Supplies	Amount	Notes
½ gallon container	1	For cabbage juice indicator
Cafeteria trays (optional)	1 per group	To pass out supplies
Coffee or spice grinder (optional)	1	
Heat source (small candle or Bunsen burner)	1 per group	Or share between stations
Lighter (optional)	1	Optional, if using the heat test
Magnifying glasses (optional)	1 per group	Or share between stations
Permanent marker	1	For labeling
Strainer	1	For cabbage juice indicator
Tongs or oven mitts	1 per group	Or share between stations
White ice cube trays or Styrofoam egg cartons	1 per group	Or share between stations

Consumables	Amount	Notes
Baking powder	1 Tbsp per group	
Baking soda	1 Tbsp per group	
Detergent	1 Tbsp per group	Should contain sodium carbonate
Flour	1 Tbsp per group	
Powdered sugar	1 Tbsp per group	
Plaster of Paris	1 Tbsp per group	
Aluminum foil	7 pieces per group	See Advance Preparation
Cabbage juice indicator	1/8 cup per group	See Advance Preparation
Vinegar	1/8 cup per group	
Tincture of iodine	1-2 tsp	
Water	2 cups per group	
Pop-top squeeze bottle	3 per group	(e.g., water or sports drink)
Straws or eyedroppers	3 per group	Optional, use if pop-top bottles for liquids are unavailable
Small cups	1 per group	For water test
Plastic spoons	10 per group	Plastic or metal
Toothpicks	10-12 per group	
Powder testing area	1 per group	Laminated paper, non-porous plate, ice cube tray, Styrofoam egg carton, or Dixie cup-sized cups
Red cabbage	2 cups	For cabbage juice indicator
Salt	½ - 1 cup	For cabbage juice indicator
Proof is in the Powder Booklet	1 per student	On pages 26-27
Testing instruction Cards	5 per group	On page 28
Masking tape	1 roll	For labeling
Paper towels	1 roll per group	Or share between stations

ADVANCE PREPARATION

Determine Tests to Use

There are many possible ways to perform this experiment. Before beginning, determine which tests will be performed on which powders. The possible tests are listed below. The tests you choose will depend on available supplies, teacher preference, and the safety protocol at your school.

For the purposes of this outline, we will use all tests. However, not all tests are necessary to identify the six powders used in the crime scene story. Depending on supplies and teacher preference, you may choose not to perform all tests. The heat test or the cabbage juice test may be omitted if desired and the remaining tests will still positively identify the crime scene powder.

Type of Test	Chemicals it will Identify
Water Test	• Some chemicals will not dissolve; others will • Some chemicals will create a temperature change (i.e., Plaster of Paris) • Mixtures of both an acid and a base will fizz (i.e., Alka-Seltzer)
Vinegar Test	• Chemicals containing a form of carbonate will fizz and create carbon dioxide gas (i.e., baking soda)
Cabbage Juice Test	• Will turn different colors with an acid, base, or neutral chemical
Iodine Test	• Chemicals containing starch will turn a deep purple color (i.e., flour)
Heat Test	• Chemicals containing sugar will caramelize (i.e., powdered sugar)

Determine Powders to Use

There are many ways to alter the powders used in the story. Some possible suggestions include:

- To adhere to the crime story but make a shorter activity, omit any of the typical bakery powders (baking soda, baking powder, or flour).
- Plaster of Paris will permanently clog drains if poured down a sink. There are a few options for avoiding this issue:
  - Have students do the tests with Plaster of Paris but remind them they must throw all materials from their tests into the trash and NOT in the sink.
  - Before students begin, model the entire experiment procedure using Plaster of Paris. Have students record the data collected as you perform the tests on this powder. They can then test the remaining powders on their own.
  - Remove the Plaster of Paris entirely from the story and the experiment. If you prefer to omit Plaster of Paris but would still like to use the crime

scene story, substitute milk powder and associate it with the landlady (who may have needed it for her many children).

Ice Cube Trays of Powders:

- ❑ Use the masking tape and permanent marker to label ice cube trays with the names of the six known powders you will be using.
- ❑ Use the masking tape and permanent marker to label six plastic spoons with the names of the six known powders you will be using.
- ❑ Add about one tablespoon of each powder into its corresponding well.
- ❑ Put the correct spoon in each well.

Powder Testing Area:

- ❑ If supplies allow, students may test the powders in the wells of a white ice cube tray, a Styrofoam egg carton, or Dixie cup-sized disposable cups.
- ❑ Alternatively, a laminated piece of paper or a non-porous plate would work. Students will simply place their powder on the plate and add a few drops of liquid on top of it. If using this method, make sure students use as little liquid as possible to test the powders. 2-4 drops will be enough for the iodine, vinegar, and cabbage juice test. The water test should be done in a cup since more water is required to see if the powder dissolves.

Detergent:

- □ The detergent must contain sodium carbonate (also called washing soda). Check the label. Try out these detergents first: Arm & Hammer Fabricare, BioKleen, or Seventh Generation.
- □ If the detergent chosen has a chunky texture that is very different from the other powders, use a coffee grinder or similar to grind the detergent until it more closely resembles the texture of the remaining powders.

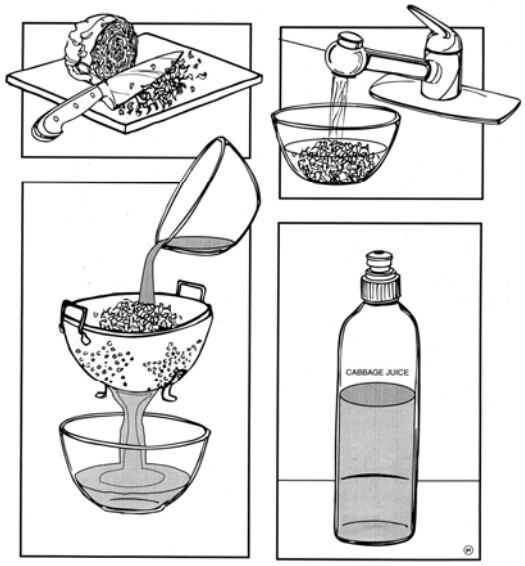
Pop-Top Bottles:

- □ Pop-top bottles (such as water bottles) are used to contain iodine, cabbage juice, water, and vinegar. You may give each group a bottle of each or share between groups.
- □ If bottles are unavailable, place these liquids in cups and have students use a straw or eyedropper to transfer just a few drops of each liquid to their powder testing area.

Cabbage Juice Indicator:

- ❑ Finely chop red cabbage with a knife.
- ❑ Place 2 cups or more in ½ gallon container.
- ❑ Add hot tap water until cabbage is just barely covered.
- ❑ Wait 2–5 minutes.
- ❑ Place strainer over large bowl. Pour cabbage and hot water through strainer, collecting water in bowl. The water should now be purple.

- Add ½–1 cup salt to the mixture and stir until dissolved (this prevents the cabbage juice from molding).
- Store the purple water ("cabbage juice indicator") in a labeled container in the refrigerator until ready for use. It does not need to be refrigerated on the day of use.
- Dispose of the solid cabbage as you would other vegetable scraps.
- Label one spoon per group "cabbage juice."



For more information on cabbage juice indicator, including a video of this procedure, see the "Of Cabbages and Kings" video listed in the Resources section (page 24).

Iodine Solution:

- Add 1 teaspoon of tincture of iodine to 2 cups of water (enough for one classroom of about 35 students).
- Divide this solution into pop-top squeeze bottles.
- Use masking tape and a permanent marker to label the bottles "iodine solution."
- Label one spoon per group "iodine."

CAUTION: Iodine is poisonous to ingest and may stain skin and clothing.

Water:

- Fill pop-top squeeze bottles with room temperature water.
- Label these bottles "water."
- Label one spoon per group "water."

Vinegar:

- Fill pop-top squeeze bottles with about 1-2 cups vinegar.
- Label these bottles "vinegar."
- Label one spoon per group "vinegar."

Heat Test:

□ Cut or tear aluminum foil into about 5 cm by 5 cm (2 inch x 2 inch) squares. Create enough squares for each group to have seven squares. Alternatively, pass out a large sheet of foil to students and allow them to tear their own smaller squares.

Student Worksheets:

□ Print the *Proof is in the Powder booklet* (one per student) and fold in half.

- □ Print and copy the Testing Instruction Cards (page 28). Depending on set up, you may wish to give each group instructions for all tests or place the directions for each test at the appropriate stations around the room.
- □ Students will also need their own notebooks or paper to record their observations.
- □ Depending on student level, you may wish to print or have students duplicate the Example Data Collection Chart (page 29) to record their data.

SET UP

Cafeteria trays are an excellent way of passing out complete lab setups to each group. Set out trays (one per group) with the following items on each tray:

For each group

- ❑ Vinegar in pop-top squeeze bottle with spoon (or in cups with straws or droppers)
- ❑ Cabbage juice in pop-top squeeze bottle with spoon (or in cups with straws or droppers)
- ❑ Iodine solution in pop-top squeeze bottle with spoon (or in cups with straws or droppers)
- ❑ Water in pop-top squeeze bottle
- ❑ Powder testing area (ice cube tray, plate, or laminated paper)
- ❑ Ice cube tray with 6 powders and 6 spoons, labeled
- ❑ 1 plastic cup
- ❑ 10-12 toothpicks
- ❑ Testing Instruction Cards
- ❑ *Proof is in the Powder booklet* (1 per student)
- ❑ 6 aluminum foil squares
- ❑ 1 candle or Bunsen burner
- ❑ Pair of tongs or oven mitts
- ❑ Magnifying glasses (optional)

With Teacher

- ❑ Paper towels
- ❑ Container of crime scene powder

INTRODUCTION

5 minutes

Notes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded.
Important points or questions are in bold.
Suggested answers are in italics.

What is a chemical? *Everything around us is a chemical - chemicals can be solid, liquid, or gas. Everything from the water we drink to the air that we breathe is made of chemicals. Some chemicals can be dangerous, but many are completely harmless or even necessary for life!*

How can we tell different chemicals apart? How do we know if a flask is full of water or something dangerous? *Chemicals that look alike can have very different properties. Chemists study these properties and can perform tests to determine what chemical they have. We should never taste a chemical if we do not know what it is!*

Today we are going to solve a mystery by examining a chemical found at a crime scene. We will have to carefully observe the chemical's properties to figure out what it is. Some of the properties we will be able to see - these are the physical properties of the chemicals. For the chemical properties, we will have to experiment to find out what they are. We will be looking for signs of chemical changes such as formation of bubbles or a change in color or temperature. As scientists, we will need to record all of our observations!

What do you think are some of the properties of chemicals we may observe? *Physical properties include color, state of matter (solid, liquid, or gas), viscosity (thickness), smell, freezing/boiling point, density, etc. Chemical properties include pH and how the mystery chemical reacts when combined with other chemicals.*

We will use both physical and chemical properties to discover the identity of a mysterious chemical today.

SAFETY PRECAUTION:
• Read the safety labels on all chemicals before beginning the activity. Make sure that you are familiar with the proper procedures in case of accidental ingestion or if a student gets a chemical in their eyes. • If available, students should wear safety glasses or goggles throughout the experiment. • Remind students not to rub their eyes and to wash their hands after the activity. • Even if you are using edible chemicals such as powdered sugar, remind students that they should never taste a chemical during an experiment. • If you are performing the heat test, make sure to review fire safety with students; remind them that they should never play with fire and know the location of the nearest fire extinguisher.

INSTRUCTOR-LED ACTIVITY

Crime Scene Story

5 minutes

Read the following story to the students. You may choose to have the mystery powder in a jar and explain that it is already been collected from the crime scene or you can recreate the crime scene and allow the students to take turns collecting a sample of the powder after they have completed testing the known powders.

Crime Scene Story

Alice owned a bakery, but no one would call her sweet. She was feuding with at least four of her neighbors. She thought the washerwoman was lazy. Her landlady had too many children, including a new baby that dared to cry sometimes. The postman was a complainer—it wasn't Alice's fault he had slipped on the bakery steps! She thought he was faking that broken foot anyway. Her greatest rival was the owner of the pastry shop down the road, a woman whose cakes and pies were legendary.

"What's so great about cakes and pies?" Alice was heard to say. "What's the matter with bread?"

Alice had plenty of enemies and she was very suspicious, so each night at closing time, she checked the street for strangers and made sure the door was locked. But late one night, when Alice was very tired, she forgot to check. She opened the door to leave and a

masked stranger rushed into the bakery!

“Give me all the money you’ve got!” shouted the stranger, holding out a big black sack.

“Not a chance,” said Alice.

She rushed at the stranger, who was caught by surprise. She shoved the burglar out the door and locked it. Alice watched the burglar run down the street, and then she called the police.

By the time the police arrived, the burglar was long gone, leaving nothing but the empty sack behind. When the police examined the sack, they found grains of white powder on it. They thought the powder was probably just an ingredient from the bakery, but wanted to test it to be sure. They also asked Alice who might have a grudge against her:

The **washerwoman** had returned one of Alice’s skirts with a faint stain, so Alice refused to pay her.
The **woman who owned the pastry shop** was Alice’s biggest business competitor.
The **landlady** could not keep her children quiet, and Alice was not going to pay the rent until she did.
The clumsy **postman** had slipped on her steps and was blaming Alice for his broken foot.

Result:
Do not reveal until after students have completed the powder testing!
After students have finished the experiment, they will determine that the unknown substance is laundry detergent. Allow students to form a hypothesis as to why this powder indicates a suspect before revealing the answer: The washerwoman would be most likely to be indicated by the laundry detergent. The sack had picked up detergent from the washerwoman’s floor.

PARTNER ACTIVITY

Powder Testing

30-35 minutes

We have collected the mystery powder that was found at the crime scene, but before we can identify it, we need to collect information on the powders it might possibly be.

Walk around the classroom with the crime scene powder and allow students to get an up-close view of the sample.

Describe the crime scene powder. *White, smooth, fine powder, etc. Answers will vary.*

What kind of powder do you think this could be?
Answers will vary. Lead students to think of powders that might be found at a bakery (flour, baking soda, baking powder) and powders that may have been found on the suspect (Plaster of Paris, detergent, powdered sugar). Depending on student level, you may wish to talk with students at this point about why these powders may have been found on the suspects (Plaster of Paris would be from the cast on the broken leg; detergent would be from the job as a washwoman; powdered sugar would be from the woman who owns the pastry shop).
Alternatively, you may wish to wait until the mystery powder has been identified and allow students to figure out why it would have been associated with a particular suspect.

As students brainstorm possible powders, pull out the powders that you have for the experiment as the students name them. Explain that the police have narrowed it down to these possibilities and now it is up to them to figure out which one matches. The possible powders include baking soda, baking powder, powdered sugar, Plaster of Paris, detergent, and flour.

How could we identify the powder found at the crime scene? *We can do tests to both the known powders and the unknown powder and see if they react in the same ways.*

What are some of the ways we can test it? *What the powder looks like, what happens when it is mixed with other chemicals, or what happens when it is heated.*

Depending on age and ability, guide students as they design what tests to run and how to run them. Alternatively, tell them what tests they will be running on the unknown powder as follows:

Give students the instructions below, then pass out the testing materials tray (See Set Up on page 8) to each group. Be sure to include the *Proof is in the Powder booklet* (on pages 26-27) for each student and the Testing Instruction Cards (on page 28) for each group. The booklet will give the students instructions, from Sherlock Holmes, how to record their results for each powder. Remind students to observe carefully and record all observations in their own notebook.

Student Instructions:

1. Five tests are listed on the Testing Instruction Cards. You can conduct any test, on any powder, in any order. Your goal is to record information in your notebook about each powder so that it can be used to identify the crime scene powder.

2. After all tests have been performed on all powders, collect one scoop of the powder from the crime scene. Perform the same tests on this powder and use the information you recorded to figure out what it is!

Points to remember:

- Be careful not to mix the powders and use a different spoon for each powder.
- Record all observations in your notebook.
- Be sure to clean out the plastic cup and powder testing area between tests.
- If using Plaster of Paris, pour any chemicals from your test into the **trash**. **Do NOT pour chemicals into the sink!** Then add a little water and wipe out the container with a paper towel.

Tests to Perform:

- **Physical Properties**
  What does the powder look like? Does it have a smell? Are there crystals or small, irregular chunks? Is it a fine or coarse powder?

- **Vinegar Test**
  Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of vinegar. Stir with a toothpick. What happens?

- **Cabbage Juice Test**
  Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of cabbage juice. Stir with a toothpick. What happens?

- **Iodine Test**
  Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of iodine solution. Stir with a toothpick. What happens?

- **Water Test**
  Add one spoonful of water to the plastic cup. Feel the outside of the cup. Add ½ spoonful of powder to the water. Mix with a toothpick. Feel the cup now. Did the temperature change? Does the powder dissolve?

- **Heat Test**
  Wrap a pea-sized amount of the powder in a piece of aluminum foil. Use tongs to hold the foil packet over a candle flame for 20 seconds. Unwrap the packet and look at the powder. Be careful as the foil will be hot. What happens?

General Suggestions

- Monitor students to see how much powder they are using. They only need a small amount (the size of a pea) for the vinegar test, iodine test, heat test, and cabbage juice test.
- Remind students to record all observations as soon as they perform a test. If they try to record their observations at the end they may not remember everything they saw.
- Before students begin the procedure, you may wish to show them the best way to smell a chemical: they should use their open hand to make a waving motion over the top of the chemical to gently move the smell towards their nose. This technique is called wafting.
- If students have experience with similar activities, you may wish to expand the activity. See the Optional Extensions section (on page 18) for more information.

Ongoing Assessment Questions

- When students do the vinegar test, ask them what gas they think is in the bubbles. *(The bubbles are carbon dioxide gas, which is created in the reaction.)*
- When students do the iodine test, ask them why it would turn black. *(The iodine reacts with starch, found in corn starch, powdered sugar, and baking powder.)*
- When students do the water test, ask them why the solution changes temperature. *(The powder is arranged differently when mixed with water and each different arrangement of molecules has a different energy; to change the arrangement of the molecules, energy is either used (cold) or given off (hot) and sometimes this change in energy is large enough to feel.)*
- When students do the cabbage juice test, ask them why the cabbage juice changes color. *(Cabbage juice is an acid-base indicator, a chemical that interacts with acids and bases and changes color.)*
- When students do the heat test, ask them why the powdered sugar changes color. (*Sugars will caramelize with heat*.)
- Listen to students' reasoning when they identify the crime scene powder. They should refer to their notebook when choosing the identity.

CAUTION: Plaster of Paris clogs drains PERMANENTLY. Caution students to throw all powders into the garbage unless they are absolutely certain the powder is NOT Plaster of Paris.

CAUTION: Iodine is poisonous to ingest and may stain skin or clothing.

WRAP-UP

10 minutes

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What type of powder was collected at the crime scene? *Students should determine that detergent was the powder found at the scene of the crime.*

Who do you think the culprit is based on the results of your testing? Why? *Answers may vary. Remind students that a washerwoman was one of the suspects and would have reason to carry a bag coated in detergent.*

Have we collected enough information to be sure it was the washerwoman? *No, the police would need more information, but this lead will be a good place to start. More advanced students should understand that many pieces of evidence are needed to solve crimes, not just one.*

What reasoning did you use to identify the crime scene powder? *Answers will vary. The results of each test narrow down the choices for the identity of the crime scene powder. Depending on the order in which the students perform the tests, they may imediately rule out certain powders. Encourage students to talk through their reasoning.*

Which tests caused a chemical change in the powders? How do you know? *The vinegar test, iodine test, heat test, water test, and cabbage juice test all caused chemical changes in some of the powders. Evidence of a chemical change can include a change in color, change in smell, change in temperature, or the formation of bubbles.*

Which tests caused a physical change in the powders? How do you know? *The water test caused a physical change in some of the powders when they dissolved. We know because there were no signs of a chemical change. Observing the physical properties of the powder (grain size, crystal formation, smell) is also not a chemical change.*

Which powders were difficult to identify? *Baking soda, baking powder, and Plaster of Paris do not show much of a temperature change, so they can be more difficult to identify. If students accidently contaminated any of their powders, it may have been difficult to identify the crime scene powder.*

Did you get any unexpected results from any of your tests? Why would your results be different than your neighbors? *The primary reason students may have found different results than expected is because of contamination. If the powders or the spoons for each powder were mixed up, or if the testing area was not thoroughly cleaned between powders, students may have gotten incorrect results. This fact sometimes happens in real labs as well so scientists must be very careful and perform tests many times to make sure the results are correct.*

Would crime scene investigators always be able to collect a large jar of a mystery substance like we did? *Often only a very small amount of a mystery substance will be found. To challenge students to think critically about how to test only a very small amount of powder, see the Advanced Lesson ideas in the Optional Extensions on page 18.*

CLEAN UP

- Do not allow students to put Plaster of Paris down the sink. Plaster of Paris will permanently clog and destroy the drain.
- All other materials may be rinsed down the sink or thrown away.

CAUTION: Plaster of Paris clogs drains PERMANENTLY. Caution students to throw all powders into the garbage unless they are absolutely certain the powder is NOT Plaster of Paris.

CAUTION: Iodine is poisonous to ingest and may stain skin or clothing.

OPTIONAL EXTENSIONS

ADVANCED LESSON

To increase the difficulty of this lab, try the following:

- Tell students only a tiny amount (about one pea-sized scoop) of powder was recovered from the crime scene. Challenge students to figure out how the powder could be identified with such a small amount. Can any of the tests use a smaller amount of powder? Are there tests that should be performed first? Can the data from one test give clues about what tests should be done next?
- Mix two of the powders together and challenge students to determine what the combination is.
- Have students choose a mystery powder and give it to their partner to identify.
- Challenge students to identify more powders. Up to 12 are included in this overview. See pages 31-33 for alternative experimental set ups.

CHEMICAL VS PHYSICAL CHANGES

Review the difference between physical and chemical changes with students. In the powder lab, which tests resulted in a physical change and which tests resulted in a chemical change? Have students perform a range of simple experiments (freezing water, burning paper, making bubbles with vinegar and baking soda, dissolving salt in water, etc.) to demonstrate physical and chemical changes and identify each type of change.
For an example lesson for younger students, visit http://sadie423.hubpages.com/hub/hands-on-experiments-to-learn-about-chemistry

ACIDS AND BASES

Have students mix a variety of household substances with the cabbage juice indicator such as lemon juice, water, detergent, and baking soda. The juice changes color to indicate whether each substance is an acid or a base. This can also be done with indicator paper.
For an example lesson on acids and bases, visit http://www.omsi.edu/sites/all/FTP/files/chemistry/NH-PDF/NH-B17-OfCabbageKings.pdf

BACKGROUND INFORMATION

This background information is for teachers. Modify and communicate to students as necessary.

This activity requires students to gather information from multiple chemical tests of various white powders. Each test shows a different physical or chemical property of the powders. Students then analyze their results and find the identity of the powder collected at the crime scene.

Substances can undergo both **chemical changes** and **physical changes**. Chemical changes alter the atomic or molecular structure of a material and produce a new substance. Examples of chemical changes include burning, rusting, and oxidizing processes; cooking an egg results in a chemical change. On the other hand, physical changes do not produce new substances. Physical changes include processes such as freezing, melting, and vaporizing; making ice from liquid water is a physical change.

One way to help determine if something is a physical or a chemical change is to think about if you could reverse the change in order to return to the same materials you started with. For example, if you freeze water to change it to ice, a physical change, the ice could be melted back to liquid water. However, if you burn paper, a chemical change, you will never be able to turn the ashes back into paper.

Tests performed:

- **Physical Properties**
  Each powder is similar in color and composition, but students may still be able to find differences (especially if they have magnifying glasses). Depending on which powders are used, they may notice the milk powder usually has a bit of a cream color. Also, the baby powder can have a faint smell. Upon inspection, students should notice that salt, sugar, and Epsom salts are **crystals**. Alka-Seltzer, detergent, and milk powder are mixtures of various powders and they appear to be tiny, irregular chunks. The rest of the powders consist of very tiny particles and are classified as **powders**.

- **Iodine Test**
  Detergent is designed to remove stains, so the iodine fades when it is mixed with detergent. Milk powder removes the color of iodine because it contains a sugar called **lactose**. This sugar reacts with the iodine in solution, changing it from brown to colorless.

Iodine can be used to test for starch. Iodine is normally a yellowish-amber color. When iodine combines with starch, it turns dark blue, purple, or black. Iodine solution contains iodine in this form, I_2, where two atoms of iodine are connected. Starch chains are in a double helix form, similar to DNA, but the helix is much wider. The center of this helix selectively absorbs certain molecules, including I_2. When the iodine solution is mixed with starch, the iodine molecules (I_2) enter the center of the helix, where they bind to the starch to form a dark blue complex. Flour and baking powder (which contain starch) will both turn blue or black. Powdered sugar often contains cornstarch so it will typically turn blue or black as well.

- **Vinegar Test**
  Several of the powders contain some form of the arrangement of atoms called **carbonate,** which will react with vinegar. There are several forms of carbonate in the powders, as shown in the following table:

sodium bicarbonate is in:	sodium carbonate is in:	calcium carbonate is in:
baking soda Alka-Seltzer baking powder	detergent	Plaster of Paris

All these forms of carbonate react with vinegar to create carbon dioxide gas bubbles.

- **Cabbage Juice Indicator Test**
  Scientists put chemicals into two important families: **acids** and **bases**. Acids and bases are opposites in chemistry. Examples of acids are vinegar, battery acid, stomach acid, etc. Some acids are non-poisonous (such as citric acid, which is found in oranges, lemons, and limes) and when they are eaten the taste can be sour. Examples of bases are household cleaners like ammonia, detergent, and drain cleaner; blood and baking soda are also basic. When people taste non-poisonous bases (such as small amounts of baking soda), the taste is often bitter or soapy.

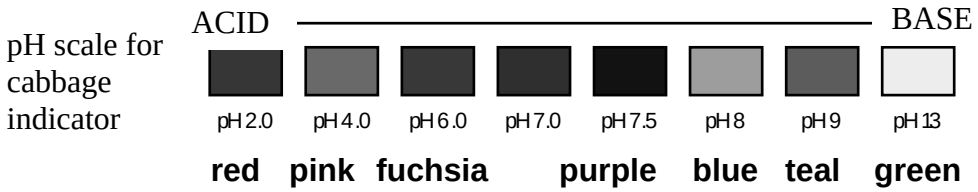
  Many chemicals can be classified as either acids or bases. For instance, rocks such as limestone are bases and they will react with weak acids such as vinegar. Plants often produce bitter bases in their leaves that discourage animals from eating them. There are also many substances that do not act as acids or bases. For instance, gasoline, table salt, mineral oil, and most plastics are not acids or bases. In addition, distilled water is neither an acid nor a base. Such substances are said to be **neutral**.

  Indicators are chemicals that tell us things we cannot see otherwise. One type of indicator is an acid-base indicator that will turn different colors

depending on whether it is exposed to an acid or a base. Cabbage juice, for instance, can change to yellow, green, or blue in the presence of a base and it can change to red or pink in the presence of an acid. Baking powder, baking soda, and detergent are all basic and will turn the cabbage juice blue or green. Cream of tartar is an acid and turns the cabbage juice red or pink.

Plant Indicators
Cabbage juice produces so many colors because it contains several indicators that react with acids and bases. The indicators in cabbage juice are all **anthocyanins**, a class of color-changing chemicals often found in flower petals and fruit juices. In fact, many plants contain "natural" acid and base indicators that produce vivid color changes. We see these color changes as flowers bloom or as fruits ripen.

Scientists use the **pH scale** to specify how much acid or base is in a solution. The pH scale goes from 1–14. A low number on the scale indicates an acid, the number 7 indicates a neutral compound (such as water), and higher numbers indicate bases. The cabbage juice pH scale is as follows:



- **<u>Temperature Test</u>**
  What does it mean to be "hot" or "cold"? If students could look at "cold" molecules in solution and "hot" molecules in solution, they would notice something right away. The "hot" molecules would all be moving, spinning, and shaking much faster than the "cold" molecules. In fact, when scientists say a substance is "hot," what they mean is the molecules in that substance are shaking and moving a lot. In general, scientists define **temperature** as the average molecular motion of a substance. Cold substances have less molecular motion than hot substances.

  Because molecules are so tiny, students can never feel them moving. Yet by feeling the temperature, students are indirectly experiencing what happens when billions and billions of molecules move, shake, and twist.

  The energy changes in this experiment come from rearranging atoms and molecules. In general, when molecules move from high-energy arrangements to low-energy arrangements, they release energy.

This process is what happens when the detergent (containing sodium carbonate molecules in a high-energy arrangement) dissolves in water. The sodium carbonate molecules are rearranged in the water, releasing energy as heat. This transfer of heat out of a chemical system is called an **exothermic** process.

The opposite process occurs when Epsom salts, which are in a lower-energy arrangement, dissolve in water. These molecules make up the energy difference by absorbing energy from the surrounding solution. This cools the water down and makes the cup feel cool. The transfer of heat into a system (in this case, to the Epsom salt molecules from the water itself) is called an **endothermic** process.

Some powders require energy to dissolve (use an **endothermic** process) and feel cold when mixed with water. Some powders release energy (use an **exothermic** process) when dissolved and feel warm when mixed with water. Epsom salts are strongly endothermic; baking powder and baking soda are only slightly endothermic. Detergent is very exothermic; Plaster of Paris is slightly exothermic.

- **Heat Test**
  Depending on how long students left the powder sugar in the flame, they may have found that it turned brown and caramelized, or perhaps burned and turned black. The carbon, hydrogen, and oxygen in sugar react with fire and turn the powder into a thick liquid. Students will find that once this liquid has cooled, it will become a hard solid instead of a powder. This result is an excellent example of a chemical change.

- **Solubility Test**
  Alka-Seltzer, Epsom salts, salt, and sugar all **dissolve** in water easily; the powders can no longer be seen in the liquid. Baking powder, baking soda, cream of tartar, and detergent dissolve in water only a little and some of the powder can still be seen in the liquid. Milk powder, Plaster of Paris, and starch do not dissolve well in water.

Real-World Applications

The ability to quickly and accurately identify unknown substances is of great importance in many professions. Forensic departments need to identify everything from drugs to poisons to explosives. To identify unknown substances, many chemists will follow a process very similar to the one that the students just performed. Chemists determine the color, smell, and texture of materials and conduct a variety of tests, then compare the results with data of known materials. Recent technological breakthroughs have resulted in even more accurate and quick identifications through techniques such as spectroscopy and microscopy.

CROSS-CURRICULAR CONNECTIONS

ART

Make Your Own Paint
Present students with a number of various (safe) natural and household items that could be used to make a watercolor or paint. Suggested items include: Kool-Aid, berries, food coloring, water, bright flower petals, flour, and cornstarch. Then, on a canvas or thick piece of paper, have the students create a drawing and see how the colors look after their mixture has dried.

BIOLOGY/ BOTONY

Identifying Unknown or Poisonous Plant Life
Have the students learn to identify the signs of potential toxicity in plants and research what poisonous plants are native to their environment.

BIOLOGY

Taxonomy: Classify Your World
Give students multiple objects or pictures to group according to their characteristics. Younger students can identify a trait and group the blocks, tools, foods, plants, pictures of animals, rocks, etc. by the traits they share. Middle students can classify items according to common traits. Older students can use the traits of the items to build a dichotomous key—a series of yes or no questions that allows the identification of the item.

LANGUAGE ARTS

Write a Mystery Story
Have students write a short story to go along with the crime scene story from this activity. Ask them to write from the criminal's point of view. Why did they break into the bakery? What happened once they were there? Where did they go after they left?

For older students, have them read the Sherlock Holmes story *The Adventure of the Devil's Foot* and then devise a short crime story where either the driving plot element is an unknown powder they need to identify or that all the clues lead up to the consumption of an unknown powder.

RESOURCES

Books

The Crime Lab Case by C. Keene
Reading Level: 4th-6th grade
While Nancy and her friends are helping with a high school "chemystery" camp that teaches how science is used to solve crimes, a real mystery involving the professor in charge begins and Nancy takes over the made-up case and the real one.

One Minute Mysteries: 65 Short Mysteries You Solve With Science!
by E. Yoder and N. Yoder
Reading Level: 4th-12th
Each story, just one minute long, challenges your knowledge in earth, space, life, physical, chemical, and general science. Exercise critical thinking skills with dozens of science mysteries (solutions included) that will keep you entertained - and eager to learn more!

Web

NOVA: Three Advancements in Forensics
This article, by NOVA, discusses major advancements in forensic science. The section on “detecting chemical impurities” talks about identifying unknown powders in the case of terrorist attacks.
http://www.pbs.org/wgbh/nova/tech/three-advances-forensic.html

Using Chemical Change to Identify Unknown Powders
This PDF is packed with similar lessons on identifying mystery powders, as well as resources for teachers.
http://www.inquiryinaction.org/pdf/chapter5/Inv5.pdf

Video

Oregon Museum of Science and Industry “Of Cabbages and Kings”
This short video walks you through the process of making cabbage juice indicator and clearly demonstrates the various colors that can be achieved by mixing the cabbage juice with different acids and bases.
http://www.youtube.com/watch?v=biy6wiXujFU

GLOSSARY

Acid	A compound with an excess of available hydrogen ions; often sour in taste.
Anthocyanins	Color-changing chemicals often found in flower petals or fruit juices; may appear red, purple, or blue depending on pH.
Base	A chemical or compound that takes up hydrogen ions; often bitter in taste.
Carbonate	A chemical made of one carbon atom and three oxygen atoms; CO_3^{2-}.
Chemical change	Changes that affect the atomic or molecular properties of a material; a new substance can be created.
Chemist	An expert in chemistry, whose profession is working with chemicals.
Crystal	A chemical in solid form; usually refers to pure solids with shiny facets and faces such as diamonds.
Dissolve	When the molecules of a solid separate and become completely surrounded by the molecules of a liquid.
Endothermic	A chemical change that absorbs energy, causing the reaction container to feel cool.
Exothermic	A chemical change that releases energy, causing the reaction container to feel warm.
Indicator	A substance that changes color to indicate the presence or concentration of a certain chemical.
Ion	An electrically charged atom or group of atoms.
Physical change	A change that does *not* create a new substance.
Powder	Composed of particles that are too small to be seen easily.
Spectroscopy	The process of splitting light into different wavelengths and studying the brightness at each wavelength.
Temperature	The degree or intensity of heat present in a substance or object.
Unknown Substances	Some kind of unknown or unlabeled substance that has ambiguous or hard-to-identify characteristics.

SHERLOCK HOLMES

221B, BAKER STREET
LONDON

Dear trusted friends have you yet figured out this great mystery? What is the unknown substance and does it reveal to you the identity of the burglar who broke into Alice's bakery? Was it the washerwoman, the woman who owns the pastry shop, the landlady, or the postman? I hope you will describe to me how you solved this investigation I look forward to hearing about your great discoveries. Please kindly return this telegram to me at once.

THE CRIME SCENE POWDER IS:
THE BURGLAR WAS:

SHERLOCK HOLMES

221B, BAKER STREET
LONDON

My name is Sherlock Holmes. I am sending you this message with great haste as a crime has been committed. I am trusting you, my faithful partners in solving a mystery, to help me bring the criminal to justice.

As you have now heard, Alice was nearly robbed in her bakery. The thief ran away, but left behind a sack containing grains of white powder. We have narrowed down the suspects to four individuals the washerwoman, the woman who owns the pastry shop, the landlady, and the postman. You will use evidence to find out which person is the thief.

You will be gathering information about a series of white powders that may have been left by the burglar. You will need to record your observations carefully and exactly. Justice depends on your good work. I have provided an example of the tests I conducted on cornstarch, but I am leaving you in charge of testing the other powders. Farewell until we next meet, hopefully in happier times.

THE INTERNATIONAL EXHIBITION OF
SHERLOCK HOLMES

SHERLOCK HOLMES

221B, BAKER STREET
LONDON

Trusted investigators, please record your careful observations in your own notebooks as I have done here. When you have finished testing all the powders, you can then run your experiments on the crime scene powder.

	Investigator: S. Holmes
NAME OF POWDER: *cornstarch*	
DESCRIPTION OF THE POWDER (COLOR, TEXTURE, SIZE, ETC.): *fine texture, bright white, very small grains, feels soft*	
TESTS CONDUCTED AND RESULTS:	
iodine test	*turns black*
water test	*forms a paste, does not change temperature*
cabbage juice test	*stays purple*
vinegar test	*nothing happens*
heat test	*nothing happens*

SHERLOCK HOLMES

221B, BAKER STREET
LONDON

My dear friends, I see that you have finished experimenting with all of the powders. Now comes your most important work of all. Please test the crime scene powder that was found in the sack left by the thief.

Investigator: _____	
NAME OF POWDER: *cornstarch*	
DESCRIPTION OF THE POWDER (COLOR, TEXTURE, SIZE, ETC.):	
TESTS CONDUCTED AND RESULTS:	

Testing Instruction Cards

Physical Properties

What does the powder look like?
Does it have a smell?
Are there crystals or small, irregular chunks?
Is it a fine or coarse powder?

Vinegar Test

Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of vinegar. Stir with a toothpick.
What happens?

Cabbage Juice Test

Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of cabbage juice. Stir with a toothpick.
What happens?

Iodine Test

Put a pea-sized amount of the powder on your powder testing area. Add ¼ spoonful (3-4 drops) of iodine solution. Stir with a toothpick.
What happens?

Water Test

Add one spoonful of water to the cup. Feel the cup.
Add ½ spoonful of powder to the water. Mix with a toothpick. Feel the cup now.
Did the temperature change?
Does the powder dissolve?

Heat Test

Wrap a pea-sized amount of the powder in a piece of aluminum foil. Use tongs to hold the foil packet over a candle flame for 20 seconds. Unwrap the packet and look at the powder. **Be careful** as the foil will be hot!
What happens?

The Proof is in the Powder

Example Data Collection Chart

Tests → / Powders ↓						
1						
2						
3						
4						
5						
6						
Crime Scene powder						

The Proof is in the Powder

Example Completed Data Collection Chart

Tests → / Powders ↓	Physical Properties	Vinegar Test	Iodine Test	Cabbage Test	Water Test	Heat Test
1 Baking Soda	Fine powder	Bubbles	Orange-brown	Blue	Colder, dissolves a little	No change
2 Baking Powder	Fine powder	Bubbles	Black, bubbles	Blue, bubbles	Colder, dissolves a little	No change
3 Flour	Fine powder	No bubbles	Black	Stays purple	Stays same temperature, turns to a paste	Burns, turns yellowish
4 Powdered Sugar	Fine powder	No bubbles	Blue	Stays purple	Stays same temperature, dissolves	Turns brown and bubbles
5 Plaster of Paris	Fine powder	Bubbles	Orange-brown	Stays purple	Warmer, turns to a paste	No Change
6 Detergent	Coarse chunks (unless blended)	Bubbles	Orange-brown color fades	Green	Warmer, dissolves a little	No Change
Crime Scene Powder	Coarse chunks (unless blended)	Bubbles	Orange-brown color fades	Green	Warmer, dissolves a little	No Change

The Proof is in the Powder

These five tests identify 12 powders

Powder	Physical Properties	Vinegar Test	Iodine Test	Cabbage Test	Water Test
Alka-Seltzer	Coarse, irregular chunks	Bubbles	Orange-brown, bubbles	Stays purple, bubbles	Stays same temp, dissolves, bubbles
Baby powder	Powder, may have a smell	No bubbles	Orange-brown	Stays purple	Stays same temp, doesn't dissolve
Baking powder	Fine powder	Bubbles	Black, bubbles	Blue, bubbles	Colder, dissolves a little
Baking soda	Fine powder	Bubbles	Orange-brown	Blue	Colder, dissolves a little
Cream of tartar	Fine powder	No bubbles	Orange-brown	Red	Stays same temp, dissolves a little
Detergent	Coarse, irregular chunks	Bubbles	Orange-brown color fades	Green	Warmer, dissolves a little
Epsom salts	Small, sharp edged crystals	No bubbles	Orange-brown	Stays purple	Colder, dissolves
Milk powder	Fine powder	No bubbles	Orange-brown color fades	Stays purple	Stays same temp, turns milky
Plaster of Paris	Fine powder	Bubbles	Orange-brown	Stays purple	Warmer, turns to a paste
Flour	Fine powder	No bubbles	Black	Purple/pink	Stays same temp, turns to a paste
Starch	Fine powder	No bubbles	Black	Stays purple	Stays same temp, turns to a paste
Sugar	Small, sharp edged crystals	No bubbles	Orange-brown	Stays purple	Stays same temp, dissolves

The Proof is in the Powder

These three tests identify eight powders

Powder	Vinegar Test	Iodine Test	Cabbage Test
Alka-Seltzer	Bubbles	Brown, bubbles	Purple, bubbles
One of: epsom salts, baby powder, salt, sugar, milk powder	No bubbles	Orange-brown	Stays purple
Baking powder	Bubbles	Black, bubbles	Blue, bubbles
Baking soda	Bubbles	Orange-brown	Blue
Cream of tartar	No bubbles	Orange-brown	Red
Detergent	Bubbles	Orange-brown color fades	Green
Plaster of Paris	Bubbles	Orange-brown	Stays purple
Starch	No bubbles	Black	Stays purple

The Proof is in the Powder

These two tests identify five powders

Powder	Vinegar Test	Cabbage Test
Alka-Seltzer	Bubbles	Purple, bubbles
Cream of tartar	No bubbles	Red
Detergent	Bubbles	Green
Baking powder or baking soda	Bubbles	Blue
One of: Epsom salts, baby powder, Plaster of Paris, milk powder, salt, sugar, starch	No bubbles	Stays purple

These two tests identify six powders

Powder	Iodine Test	Cabbage Test
Alka-Seltzer	Brown, bubbles	No color change, bubbles
Baking powder	Black, bubbles	Blue, bubbles
Baking soda	Orange-brown	Blue
Cream of tartar	Orange-brown	Red
Detergent	Orange-brown color fades	Green
Starch	Black	Stays purple
Baby powder, Epsom salts, sugar, Plaster of Paris, salt, milk powder	Orange-brown	Stays purple

SUPPLY WORKSHEET

The Proof is in the Powder

Recommended group size: 2-3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Note: This list assumes you will be testing six powders with five tests; modify supplies as needed.			
½ gallon container	1		
Aluminum foil	7 squares (2”x2”) per group		
Baking powder	1 tablespoon per group		
Baking soda	1 tablespoon per group		
Cafeteria trays (optional)	1 per group		
Candles	1 per group (or share between groups)		
Detergent	1 tablespoon per group		
Flour	1 tablespoon per group		
Ice cube trays (to distribute powders)	1 per group (or share between groups)		
Lighter	1		
Magnifying glasses (optional)	1 per group		
Masking tape	1 roll		
Paper towels	1 roll per station or group		
Permanent marker	1		
Plaster of Paris	1 tablespoon per group		
Spoons (for powders and liquids)	10 per station or group		
Pop-top squeeze bottles (e.g., water or sports drink) 6 oz. or larger	3 per group (or share between groups)		
Powder testing area (ice cube tray, non-porous plate, or laminated paper)	1 per group		
Powdered sugar	1 tablespoon per group		
Red cabbage	2 cups		
Salt	½-1 cup		
Small cup (for water test)	1 per station or group		
Strainer	1		
Straws or eyedroppers (optional)	3 per group		
Tincture of iodine	2 tsp per class		
Tongs or oven mitts (to hold foil over flame)	1 per group (or share between groups)		
Toothpicks	10–12 per station or group		
Vinegar	1/8 cup per group		
Water	2 cups per group		
Coffee grinder (optional)	1		