No Hassle Messy Science with a Wow

Chemistry in the K–8 Classroom

OREGON MUSEUM OF SCIENCE AND INDUSTRY

Portland, Oregon

No Hassle Messy Science with a Wow:
Chemistry in the K–8 Classroom

2nd Edition

A Project of the Camille and Henry Dreyfus Foundation

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1945 SE Water Avenue
Portland, OR 97214
www.omsi.edu

Library of Congress Catalog-in-Publication Data
Pending

ISBN: 978-0-9799206-0-8

Printed in the United States of America

03 04 05 06 07 08 09 10 11

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Acknowledgements

We would like to thank the following people for their invaluable contributions to the success of this project:

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Susan Swain
Nalini Uppaluri
Suzie Womack

Chemistry Lab Staff and Volunteers

These people played key supportive roles.

Daniel Akita
Sabrina Chartier
Sarah Crunelle
Amy Doerner
David DiTullio
Andrew French
Ian Gard
James Hart
Ryan Hunt
Michael Jee
Muhammed Khalifa
Kyra Kim
Anders Liljeholm
Tim Mansour
Nina Mejia
Rose Nabahet
Josh Norville
Ricardo Pérez Méndez
Julie Pirault
John Purrett
Scott Randoll
Hal Smith
Isha Tirumali

and many others

Introduction

No Hassle Messy Science with a Wow: Chemistry for the K–8 Classroom serves as an aid for teachers bringing chemistry to their elementary and middle school students. Together with the workshop of the same name, it has brought science education to diverse audiences. Teachers across the United States and internationally have used this curriculum to inspire wonder in their students.

From the beginning, classroom teachers were included in the design of this book. They met in focus groups, served on advisory committees, and offered detailed critiques of activity goals, design, and materials. All activities were tested in classrooms with students ranging from kindergarten through middle school.

Content was reviewed extensively by high school teachers and college professors. Relevance and ease of use was evaluated by elementary and middle school classroom teachers. Fun and "Wow Factor" were tested by kids of all ages.

This guide was originally developed through a grant by the National Science Foundation in conjunction with the exhibit *Experiencing Chemistry*, a hands-on chemistry lab at the Oregon Museum of Science and Industry.

For its second edition, funding for this project was generously provided by the Camille and Henry Dreyfus Foundation.

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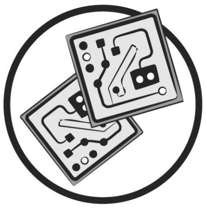
E. Chemistry of Food



F. Industrial Chemistry

G. Crime Scene Chemistry

Appendix

Activity Alignments

Reference

Posters

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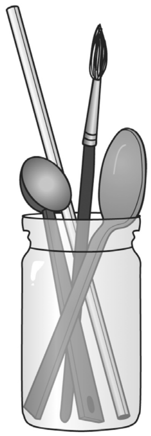
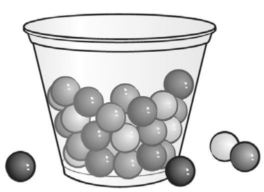




Unit Graphic

Sample Activity

Learning Objectives: *Brief objectives state what the students learn.*

GRADE LEVEL

approximate grade level

For a complete list, see the Appendix p Z – 2.

SCIENCE TOPICS

The key science topics addressed in the activity are listed here.

For a complete list, see the Appendix p Z – 4.

PROCESS SKILLS

The main process skills addressed in the activity are listed here.

For a complete list, see the Appendix p Z – 6.

GROUP SIZE

recommended group size

SNEAK PEAK inside …

ACTIVITY

Brief description of what students do in the activity.

STUDENT SUPPLIES

see next page for more supplies

The main ingredients are listed here. A more detailed list follows on the next page.

ADVANCE PREPARATION

see next page for more details

The most time consuming steps are listed here. More detailed instructions follow.

OPTIONAL EXTRAS

These are ideas to introduce the activity, extend the activity, or provide extra experiences for your classroom.

DEMONSTRATION

The titles of optional teacher demonstrations are given along with their page numbers.

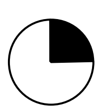
EXTENSIONS

The titles of optional extensions are given along with their page numbers.

TIME REQUIRED

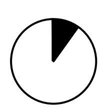
Clocks in actual activity are larger.

Advance Preparation



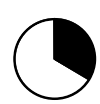
Estimated time to prepare all the materials for the activity.

Set Up



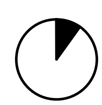
Minimum time to set up the activity immediately beforehand.

Activity



Estimated time for the class activity; does not include time for discussion.

Clean Up



Minimum time for cleaning up.

SUPPLIES

Item	Amount Needed
All materials needed to perform the main activity are listed here.	
If a specific brand is recommended, the brand is listed after the item as well.	
Example: sealing plastic bags (e.g., Ziploc™)	1 per student

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Solution, item, or equipment to prepare:

- Step-by-step directions to make solutions or prepare equipment are given here.
- Be advised that the first time preparing an activity may take longer.
- Instructions for storing solutions are given here.

CAUTION: Cautions are bold and in a box.

Notes and Hints

- Advice about where to purchase special ingredients is given here.
- Also, any possible substitutions are listed here.

SETUP

For each group

- A checklist of items to set out for students.

At a central location (or with the teacher)

- A checklist of items to be shared in the classroom.

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

The purposes of this section are to:
- find out students' prior knowledge on the topic
- focus the students' attention on a question to investigate
- make the topic relevant to students

This is typically a script, but may include other directions.

Questions to ask the students are in bold.
A guide to student answers is in italics.

TEACHER DEMONSTRATION

Teacher demonstrations can occur before, during, or after activities, and they can have many purposes. They can:
- fill waiting time during the activity
- engage students as an introduction to the activity
- summarize concepts after activity completion
- provide interesting extensions of the activity that are too dangerous or expensive for students to conduct

Demonstration Title

A brief description of the demonstration along with supplies, instructions, and scientific explanation are included with the demonstration.

Supplies needed for Demonstrations are also listed in the Supply Worksheet at the end of the activity.

The activity name and approximate grade level are also listed at the bottom of each page.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page XX, working in groups of XX. Below are suggestions to help the teacher facilitate the activity.

NOTES

Sample Activity

SCIENTIFIC PROCEDURE

This shows a reduced picture of the scientific procedure for reference.

Page reference for the master is given here.

Running Suggestions

- Mentions difficult steps in procedure, or possible ways the activity could go wrong. Strategies to prevent these problems are listed here.

Ongoing Assessment

- Gives questions to help focus students and lead them to better understanding. *(Answers are here.)*
- Another set of questions that may be useful during the activity is in the Classroom Discussion section which follows.

Misconception Alert: If there is a misconception likely in the activity, it is listed here. Strategies to dispel misconceptions are given.

Safety and Disposal

- If goggles should be worn during the activity, it is mentioned here.
- Describes procedures for cleaning up after the activity. Mentions whether materials can/cannot go down the sink, can/cannot go in the trash, can/cannot be reused.

CAUTION: Cautions are in bold and in a box.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

The purposes of this section are to:

- collect observations or data from students
- summarize the events of the activity
- allow students to create explanations for the events of the activity
- collect new ideas for students to investigate

This is typically a script, but may include other directions.

These questions may also be used during the activity as Ongoing Assessment.

Questions to ask the students are in bold.
Possible student answers are in italics.

EXPLANATION

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

This section explains the scientific principles and concepts presented in the activity.

BACKGROUND FOR ALL GRADES

Some Explanations are divided if the activity is for a large age range. The first section gives the basic explanation for all grades. Finer points are detailed in a second section under the heading **EXPLANATION FOR GRADES XX-XX**

Vocabulary listed in the Explanation is in **bold**. The vocabulary section lists all vocabulary with their definitions.

Misconception Alert: If there is a misconception likely in the activity, it is listed here. Strategies to dispel misconceptions are given.

EXTENSIONS

Optional extensions are given. These extensions can be:

- minor changes to the current activity (substitution or addition of ingredients)
- an alternative method of conducting the investigation
- an Inquiry Opportunity

Each extension has a title, brief description, supply list, activity instructions, and extra explanation.

CROSS-CURRICULAR CONNECTIONS

To integrate curriculum across subjects, ideas for potential activities and projects are listed. If a specific resource is mentioned, that resource is listed in the Resources section.

RESOURCES

References to Web sites, books, and other lesson plans are listed here. These resources can be used for Cross-Curricular Connections, for Extensions, or to otherwise enhance the learning experience for students.

A compiled list of all resources from all the activities is included in the Resource List section of the Appendix. This Resource List is also available **on the supplemental CD** and online at **www.omsi.edu/k8chemistry**.

VOCABULARY

This section lists vocabulary and definitions for all bold words in the Explanation section. Vocabulary that may come up in demonstrations, discussion, or extensions is also listed.

A compiled list of all vocabulary from all the activities is included in the Glossary section of the Appendix. This Glossary is available **on the supplemental CD** and online at **www.omsi.edu/k8chemistry**.

SCIENTIFIC PROCEDURE

Step-by-step directions for students include:

- pictures for extra clarity
- questions for students to answer during the activity
- instructions for how to clean up.

In some activities, data sheets are also included.

These student handouts are available in English and Spanish on the supplemental CD.

SUPPLY WORKSHEET

This worksheet lists all materials needed for the main activity as well as for all Extensions and Teacher Demonstrations. If teachers fill out this worksheet, a copy of the completed worksheet can be given to an assistant or parent helper to gather or purchase the necessary supplies.

Supply worksheets for all activities are **available on the supplemental CD** and online at **www.omsi.edu/k8chemistry.**

Scientific Inquiry

See a colorful shimmering liquid with a surface of bubbles. Put a plastic ring in the solution. See a thin film of liquid span the ring. Blow on the film. A bubble! It escapes the ring and sails off into the sky. When you blow again, nothing happens. Is it because the ring has no film across it? Test this. Put the ring back in the solution; see the thin film across the ring. Blow again, make another bubble.

What happens if you blow softly?
What happens if you blow strongly?
Can you catch a bubble?

You've just read an experience of scientific inquiry. Scientific inquiry is a process that encourages us to become actively engaged in studying a subject. We make observations, and from these observations we form questions. If we want to answer the questions, we design tests to find the answers. Knowing the answer will create new observations, along with new questions, and new investigations.

As our learning strategies develop, we refine our scientific inquiry process. We start to ask questions that are more specific. Our investigations become more sophisticated to answer these questions. We design scientific experiments that control variables and form conclusive evidence.

Because scientific inquiry encourages active engagement, it leads to a better understanding of whatever topic we study. It mimics the natural process we use to investigate and understand our world. By embracing the inquiry process in your classroom instruction, you can foster the scientist in every student.

With the current emphasis on teaching students science content, some teachers may feel there is not time to teach scientific inquiry as well. This apparent struggle between content and inquiry does not need to exist. Instead, scientific inquiry can be a powerful tool to help you teach content in your classroom.

Forms of Inquiry
There is no single correct way to perform scientific inquiry. Rather, there is a continuum of formats, and students can work at different places on the continuum depending on the learning goals.

The simplest inquiry is in the form of **structured inquiry**. Students have a step-by-step procedure that they use while learning a scientific concept. In this format, the teacher serves as a guide for how to design a scientific experiment and what features make a scientific investigation successful.

An intermediate form of inquiry is **guided inquiry**. In this format, students are responsible for designing a portion of the investigation, and the teacher is responsible for the rest. For instance, students may be given a specific question to investigate, but the process by which they investigate that question is left to the students to design. Teachers can assist students as they design their experiment but should allow students to make their own decisions. For meeting Oregon State Science Standards, students can be evaluated on the part of the investigation for which they are responsible.

The most open-ended format is **student-initiated inquiry (or open inquiry)**, where students generate their own question to investigate and then design their own experiment to answer this question. This type of investigation includes all aspects of scientific inquiry evaluated in the Oregon State Science Standards.

When incorporating scientific inquiry into your classroom, you can work in any part of the continuum. When students are learning new concepts, it may be more appropriate to use structured inquiry, so students can focus more on the content. As students become more familiar with the content, they will start to generate their own questions, leading to guided inquiry and student-initiated inquiry.

Fostering the Inquiry Process
Here are some strategies you can use to incorporate scientific inquiry into any of the activities in this book, as well as other activities your class undertakes.

For structured inquiry:

- ❑ Discuss the design of the activity.
  Discuss why each step in the activity is necessary. Work with students to identify which variable in the experiment is being tested and which variables are being held constant.
- ❑ Ask for predictions.
  When introducing an activity, ask students what they think will happen. Challenge students to defend their predictions with their previous knowledge.
- ❑ Share what we've learned.
  An essential part of any scientific endeavor is to share what knowledge was gained from an investigation. Allow students to present their observations, data, or new information to each other.

For guided inquiry:

- ❑ Don't use a procedure sheet.
  Even though Scientific Procedure handouts have been provided for every activity in this book, you are not obligated to use them. As an option, work with students to help them create their own methods to investigate the question.
- ❑ Use evidence to support claims.
  When students state the answer to the question, they should defend their answers with data and evidence from the activity.

For student-initiated inquiry:

- Follow up the activity with further investigations.
  Every activity in this book has optional Extensions that broaden the investigation to new areas. Some of these Extensions are labeled as Inquiry Opportunity, indicating that they are especially appropriate for student-initiated inquiry.
- Explore the unknown.
  Your students may come up with a question that isn't included in the Extensions. Very exciting! Provide support for students as they investigate their questions.

Scientific Inquiry and Standards
The process of scientific inquiry is a natural extension of how we analyze and make sense of our world. It is complicated but can be divided into different aspects. The National Science Teachers Association (NSTA), the Oregon State Science Standards, and the scientific community all use different terms to describe these aspects.

The included table correlates and defines these different terms. Notice that even though the terms may be different, the purpose of each section remains the same.

NSTA	OR State Standards	Scientific Paper	Purpose
Connecting	Forming	Introduction Background Information	States the question being investigated. Provides a background for why the question is interesting or important. Describes what is already known about the topic.
Designing	Designing	Materials and Methods Experimental Design	Lays out the procedure the investigator uses to answer the question. Details materials used in the investigation.
Investigating	Collecting	Data and Observations	Provides data collected from the investigation. Organizes information gained from the investigation for ease of interpretation.
Constructing Meaning	Analyzing	Conclusion Discussion	Uses information from the investigation to answer the original question. The experimental design is evaluated to see if it effectively helped to answer the question. In some cases, new questions are discovered that could lead to further investigation(s).

For purposes of meeting the Oregon State Science Standards, students can meet the Scientific Inquiry standard in different ways. Depending on the level of comfort you and the student have with scientific inquiry, you can choose a place on the continuum between guided inquiry and student-initiated inquiry. For example:

- A student completes an investigation, completely independently, through student-initiated inquiry. For a student who does this, you can evaluate performance on one investigation in all four dimensions: Forming, Designing, Collecting, and Analyzing.

- A student completes multiple investigations through guided inquiry. In each investigation, the student is responsible for one or more pieces of the investigation. For a student who does this, you can evaluate performance on each investigation in the dimension(s) the student completed independently. For the two dimensions Designing and Collecting, the student must perform them together on the same investigation. However, the requirements for the other two process skills, Forming and Analyzing, may be met on different investigations.

Variables and Constants

In a scientific experiment, a **variable** is a part of the experiment that can be changed or altered. As an example, in the activity ***Kool Colors***, students place steel wool into solutions of colored Kool-Aid. There are many variables that could be changed: the temperature of the Kool-Aid solution; the amount of Kool-Aid solution; the concentration of Kool-Aid solution; the flavor of Kool-Aid; the amount of steel wool used; the amount of time the steel wool is in solution.

When scientists design an experiment to answer a specific question, they work hard to change only one variable while keeping the other variables **constant**. Constants are parts of the experiment that do not change or cannot be changed. In ***Kool Colors***, students only change the temperature of the Kool-Aid solutions. Everything else in the experiment remains constant (the amount, concentration, and flavor of the Kool-Aid, the amount and time the steel wool is added).

By holding all the variables constant except for one, scientists can be sure that whatever effect they are measuring is due only to changes in that one variable. Sometimes, when scientists hold a variable constant, they say they are "controlling" that variable.

This is more reasonable than it might first appear. If a baker, for instance, wanted to see if more frosting on donuts made them taste better, the baker would change only the amount of frosting, but nothing else in the recipe. If the baker changed two parts—say, by increasing the amount of butter AND the amount of frosting—we wouldn't be sure if the donuts tasted better because of the increase in frosting or the increase in butter. When only one part of the experiment varies, it is much easier to compare results and figure out what is happening.

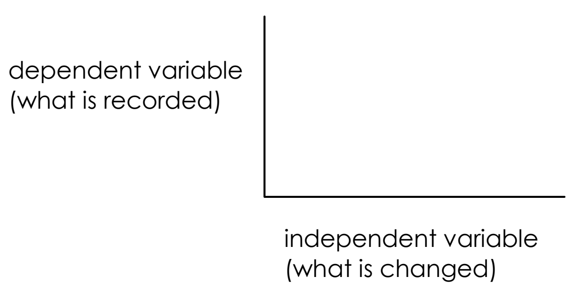
Dependent and Independent Variables
When graphing and reporting results, scientists (and students) need to be aware of what variable they are changing and what result they are measuring. This means they need to be aware of two additional terms: **independent variable** and **dependent variable**.

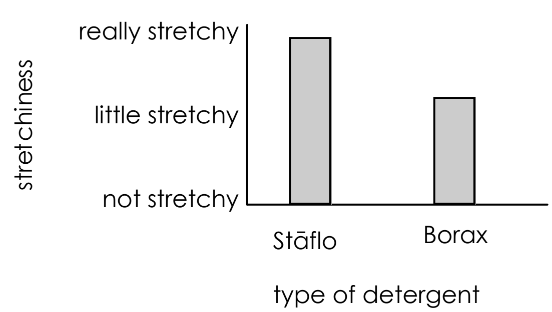
An **independent variable** is the variable that is purposely changed by the experimenter. As an example, in the activity ***Choose Your Ooze***, students test different recipes when they mix together glue and detergent. In each pair of recipes, one variable changes (the type of detergent). Type of detergent is the independent variable. The other variables (type of glue, the amount of glue, the amount of detergent) all stay the same, so these are constants or controlled variables.

A **dependent variable** is whatever is recorded by the experimenter. In ***Choose Your Ooze***, when students make changes to the recipe, they look for resulting changes to the ooze. The ooze may become more stretchy, more sticky, or more brittle. The ooze performance is the dependent variable. Notice that the dependent variable changes in response to the independent variable. The dependent variable thus depends on the independent variable.

In summary—the independent variable is what a scientist changes, while the dependent variable is what the scientist records.

When graphing results, the independent variable and dependent variable have specific places in the graph. The independent variable is on the horizontal axis (the x-axis). The dependent variable is on the vertical axis (the y-axis). See the graphs below for a general example and an example from ***Choose Your Ooze***.





RESOURCES

Web – http://en.wikipedia.org/wiki/Dependent_and_independent_variables
A good introduction to dependent and independent variables with various examples.

Web – http://www.nwrel.org/mec/science_inq/index.html
This is the Northwest Regional Educational Laboratory Science Inquiry Model Web site. This is a thorough site that supplies teachers with definitions of science inquiry, scoring guides, teaching strategies, and resources.

Web – http://www.nsta.org/about/positions/inquiry.aspx
This site has the official position about Scientific Inquiry from the National Science Teachers Association.

Web – http://www.ode.state.or.us/teachlearn/real/standards/default.aspx
The Oregon Department of Education Web site has many resources for teachers. To get specific information about scientific inquiry standards, choose the subject "Science" and search for the strand "Scientific Inquiry."

Kramer, Stephen P., *How to Think Like a Scientist: Answering Questions by the Scientific Method*
Reading level: 4th to 7th grade
Humorous and appealing pictures accompany explanations of how to use the scientific method to answer questions. Also points out the problems encountered when the scientific method is not followed correctly.

Blanford, Millie and Camplair, Patience, *Teaching The Scientific Method: Instructional Strategies To Boost Student Understanding*
The lessons in this book enable students to solve problems using the scientific method, conduct research, use scientific equipment appropriately, construct and explain tables, graphs, and reports, and develop experiments independently.

Worth, Karen and Grollman, Sharon, *Worms, Shadows, and Whirlpools: Science in the Early Childhood Classroom*
This book furthers the notion that even the littlest learners are powerful thinkers. Identifies important skills and concepts appropriate for the very young. Contains many examples of teacher stories, children's work, and commentary.

Chaille, Christine and Britain, Lory, *The Young Child as Scientist: A Constructivist Approach to Early Childhood Education, 3rd Edition*
The authors of this book focus on how children have "wonderful ideas" and when collaborating, can use a social process to construct meaning from experiences. Practical examples and theory are presented.

Chemistry Lab-in-a-Box

This curriculum is considered "No Hassle" because it does not require specialized equipment or chemicals. Use this section as a shopping list to gather supplies for your classroom. All materials can be found at supermarkets, office supply stores, craft stores, or hardware stores.

EQUIPMENT

There are some pieces of equipment that are used in virtually all activities. Designate an easy to access area of your classroom to store these materials. You may choose to have students collect these items and bring them in for use in your classroom.

Masking Tape and Permanent Markers

- Make these available to students for all activities. Encourage them to label materials as needed.
- When preparing an activity, always label all bottles, cups, or other containers to show their contents.
- Use multi-colored tape and markers to color code labels for ease of sorting.

Sponges and Towels

- Make these available to students for all activities.
- Hands-on experiments can be very exciting, and the curriculum is called "Messy Science" for this reason!

Cafeteria Trays

- When students do their experimenting on trays, any spills are contained in a small area.
- These are also useful for carrying and distributing equipment.

Pop-top Squeeze Bottles (e.g., water, sports drink)

- These help for transporting and measuring liquids in the classroom and minimize the need for clean up.
- Once you fill and label a class set of liquids, you can keep it on hand indefinitely (e.g., ammonia, water, vinegar, alcohol).

Sealing Plastic Bags (e.g., Ziploc)

- For reactions that need to be mixed well, these bags keep the reaction contained.
- Keep a variety of sizes on hand (e.g., snack, sandwich, pint, or quart)
- While more expensive, it is usually better to get the name brand bags since they are more durable.

Plastic Cups

- Some activities require clear cups, so purchase and store only these.
- Keep a variety of sizes on hand (e.g., 8oz., 9oz., or 12 oz.).
- These are used for reactions or for distributing materials.
- Wash and reuse for several activities.
- Once you label a set of plastic cups for an ingredient (e.g., salt) you can store these labeled cups with the salt and reuse them for future activities.

Styrofoam or plastic egg cartons

- Students can use these for completing multiple small reactions.
- Also, egg cartons can be used to distribute small amounts of multiple chemicals.
- White ice cube trays also work well for this.

MEASUREMENT

To make this curriculum "No Hassle," the activities have been designed so that precisely measured amounts (either in standard or metric) are not necessary for a successful experiment.

For the activities in this book, students are instructed to use a "spoonful" of material. The exact size and kind of the spoon (metal or plastic) is unimportant in most experiments. Spoons should be around a teaspoon size (think of a cheap plastic picnic spoon). Make sure that all the spoons students are using are about the same size.

It is important that the spoons be used the same way throughout the experiment. When you conduct these experiments with your class, take some time to discuss how to measure "a spoonful." For liquids, perhaps "a spoonful" is as much as you can put in the spoon. For solids, you can distinguish between a "heaping spoonful" (as much on the spoon as can fit) and a "level spoonful" (use a pencil to level the amount along the edge of the spoon).

For some extensions of the activities, students are required to use accurately measured amounts. You should have sets of measuring spoons, rulers, and measuring cups (either in metric or standard) for students to use in these situations.

SUPPLIES

This is a list of non-perishable items for all of the activities in this book. Stock up on these materials so you can do any activity on a whim!

Items available at a supermarket (e.g., Fred Meyer, Kmart, Wal-Mart, Target)

Alka-Seltzer
ammonia
baby powder
baking powder
baking soda
bleach
borax detergent
coffee filters
cornstarch
cream of tartar
extracts and flavorings (an assortment: almond, peppermint, lemon, orange, coconut, etc.)
Epsom salts
flour
food coloring (red, green, blue, and yellow)
isopropyl alcohol 70% (rubbing alcohol) and 90% or 99%
Kool-Aid, unsweetened packets (grape, black cherry, cherry, strawberry, watermelon-cherry, orange)
laundry detergent (must contain sodium carbonate)
M&M's
marshmallows, large
meat tenderizer
Mentholatum or Vicks VapoRub
microwaveable popcorn
plastic cups, clear, various sizes
powdered milk, non-fat
rice
salt
spices (an assortment: ground cloves, cinnamon, nutmeg, etc.)
sealing plastic bags, (e.g., Ziploc) snack, sandwich, pint, or quart size
spoons
Stāflo liquid starch
strainers
straws, clear
sugar, granulated white
tincture of iodine
towels and sponges
turmeric
vegetable oil
vinegar, white
watercolor paper
wax paper cups (e.g., Dixie) (4 oz.)

Items available at office supply or craft store (e.g., Office Depot, Michael's)

8 ½" x 11" plastic protective sleeves
balloons
black paper
biodegradable packing peanuts (e.g., Biofoam)
chalk
clear glue, 4 oz. bottle
clear tape
envelopes, any size
marbles
masking tape
permanent markers (e.g., Sharpie)
plaster of Paris
rulers
Styrofoam peanuts
scissors
small boxes of the same size (approx. 4-inch cubes)
small paintbrush (e.g., watercolor brush)
steel paper clips (or other small iron-containing objects)
tempera paint (dry and liquid)
transparency sheets (optional)
water soluble markers, various brands (e.g., Vis-à-vis, Flair, Mr. Sketch)
white glue (e.g., Elmer's), 4 oz. bottle
wooden craft sticks

Items available at hardware or home improvement store (e.g., The Home Depot, Lowe's, Ace, TrueValue)

battery, 6-volt lantern
calcium chloride
drill with ⅛" bit (or small screw and screwdriver)
gravel
nails, screws, bolts, or other heavy metal scraps
sand
steel wool, fine grade
wooden block or scraps of wood

Big Things Come in Little Packages

Learning Objectives: *Objects that are the same volume but different weights have different densities.*

GRADE LEVEL

K–5

SCIENCE TOPICS

Physical Properties
Techniques

PROCESS SKILLS

Comparing and Contrasting
Measuring
Organizing Data
Evaluating

GROUP SIZE

1–2

SNEAK PEAK inside …

ACTIVITY

Students learn about density by comparing gift-wrapped packages that are the same size but have different densities.

STUDENT SUPPLIES

small boxes, all same size
coins, nails, screws, bolts, or other heavy metal scraps
wood blocks or scraps
foam rubber, Styrofoam peanuts, or large marshmallows
gift wrapping paper

ADVANCE PREPARATION

Fill boxes with different materials and wrap.

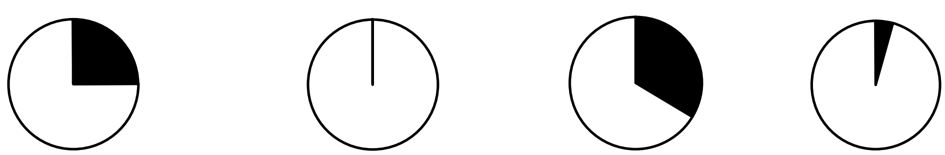
OPTIONAL EXTRAS

EXTENSIONS

Twenty Questions (p. A - 6)
Determining Volume (p. A - 6)
Determining Density (p. A - 7)

TIME REQUIRED

	Set Up	Activity	Clean Up
15 minutes	**0 minutes**	**20 minutes**	**2 minutes**



SUPPLIES

Item	Amount Needed
small boxes of the same size (approx. 4-inch cubes)	3 per class
coins, nails, screws, bolts, or other heavy metal scraps	enough to fill box
wooden block or scraps of wood	enough to fill box
foam rubber, Styrofoam peanuts, or large marshmallows	enough to fill box
gift wrapping paper and tape	enough to cover each box

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Boxes:

- ❑ Make sure that all three boxes are the same size and shape. (A cut-down half-gallon milk carton works well as a box.)
- ❑ Fill one box as full as possible with heavy metal scraps, nuts, bolts, screws, etc.
- ❑ Fill a second box as full as possible with a block of wood or scraps of wood.
- ❑ Fill the third box (without making the box bulge) with foam rubber, Styrofoam peanuts, or large marshmallows.
- ❑ Gift wrap the three boxes. You can wrap the three boxes identically or wrap them differently so that the students will have an additional criterion for comparing the three boxes.

SETUP

- ❑ none

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this acitivity, students will have the opportunity to compare gift-wrapped packages that are the same size but different densities.

Have the class look at (but not touch!) the three gift-wrapped boxes. By not allowing the students to touch or feel the boxes, you will limit the information they can gather and also increase their curiosity.

Atoms and molecules are also impossible to touch and feel directly, yet scientists are still curious about them. Scientists use the properties of materials to learn about the atoms and molecules inside them.

What is alike about the packages?
They are the same size or volume, they take up the same amount of space, they are all boxes, and they are all wrapped as gifts.

What might be different about the packages?
They could be different weights, different values, filled to a different degree, etc. It's hard to tell by just looking.

Without having the students lift or touch the boxes, ask:

Which box do you think is heaviest?
You can make a bar graph of student responses:

Column one = number of students who think box 1 is heaviest.

Column two = number of students who think box 2 is heaviest.

Column three = number of students who think box 3 is heaviest.

Column four = number of students who think all boxes weigh the same.

Have the students hypothesize what is in the packages. This will not be a very informed hypothesis because they have very little information. The only clue they have is package size.

CLASSROOM ACTIVITY

This activity does not have a Scientific Procedure. Instead, lead the activity according to the directions below.

NOTES

One of the best ways to find out what's inside the box is to measure as many things as possible about the box, such as the weight, size, shape, color, etc.

Here is a fun way to demonstrate the different weights of the boxes to the class.

1. Have three volunteers come forward (preferably including one very small student and one very large and apparently strong student).
2. Give the lightest weight package (the foam or marshmallows) to the smallest volunteer. Give the heaviest package (metal) to a strong volunteer.
3. Ask the three students to do arm lifts with their package. If the packages are on the small side, the students may need to extend their arms to experience the weight difference as they do arm lifts.
4. Ask the class to count the number of arm lifts each student can do with the package over a period of time (about 1 minute). Compare the number of arm lifts for each package.
5. Ask the volunteers how difficult the task was. Compare their answers.
6. Ask the class: What might be different about the packages? Which box is heaviest? (You can make another bar graph of student responses.) Ask the class: Who changed their minds about which package is heaviest? On what did you base your decision?
7. If it is still not clear which package is heaviest, give several (or all) students the opportunity to lift each of the packages and compare.
8. Have students hypothesize again what is in the various packages. They have more information, or data, now. When scientists make a hypothesis, they base it on all the information they have.
9. Now have three volunteers unwrap the package and inspect the contents. They can show the class, or play "20 questions" with the class, allowing the class to gather more information by asking questions.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Scientists use density to describe how heavy something is compared to its size. Objects that are the same size but different weights have different densities.

Which box is heaviest: the one with metal, foam, or wood?
metal

Which is lightest?
foam

Density is mass (similar to weight) divided by volume (size). When two things are the same size, the heavier one is more dense. Which box is least dense?
foam

Can you think of some very dense objects?
metal objects, rocks, etc.

Can you think of some objects that are not very dense?
balloons, marshmallows, pillows, an empty box, etc.

EXPLANATION

Scientists study objects by learning about their properties. Color, size, and shape are all properties that allow scientists to study what objects look like. In this activity, students learn that even when things look alike, there are still other properties that allow them to tell objects apart.

The Matter Around Us

All **matter** is made of **atoms**. Atoms combine to make **molecules**. Atoms and molecules are too small to see, but, together, they make up all stubstances. To find out how much matter is in a substance, scientists weigh the substance to find its **mass**. The more matter an object has, the more mass it has.

Density

In this activity, students study three objects that all have the same **volume**, that is they each take up the same amount of space. The three boxes all look the same, but students find out that they all have a different amount of mass; they each weigh a different amount. When scientists compare an object's mass to its volume, they call this property the **density** of the object.

The lightweight package contained foam, Styrofoam, or marshmallows. In these substances, the atoms and molecules are not packed together very tightly. There is not very much matter packed into the space. For this reason, the package has the least mass and is the least dense.

The metal-filled box was the most dense because the atoms in metals tend to be packed very tightly. Each particular type of metal has its own density; for example, lead is much denser than aluminum. The atoms in lead are larger and more tightly packed than the atoms in aluminum.

Sink or Float?
The concept of density explains why things sink or float in water. If a solid (like wood) is less dense than water, it will float on the water—regardless of its weight. For instance, pianos float on water, even though they are very heavy, because they are made of wood, which is less dense than water. On the other hand, solids that are more dense (like metals) will sink in water. Even a piece of metal as light as a dime will sink in water, because the metal is more dense.

For more examples and discussion about density, see the Explanation section in the activity **Density Rainbow**.

EXTENSIONS

Extension A: Twenty Questions
Have the students bring in gift-wrapped boxes. Let other students hypothesize what is in them. Let other students lift the packages. They can play 20 questions with each owner.

Extension B: Determine Volume (Grades 3–5)
Students determine the volume of the three boxes.

Extra Supplies
- ruler (inch or centimeter)

Extra Instructions
- Measure the width, length, and height of the boxes. (Be sure to use the same units for each measurement.)
- Determine the volume by using the following equation:

volume = width x length x height

- If students measured the dimensions in inches, then the volume is measured in cubic inches. If students measured the dimensions in centimeters, then the volume is measured in cubic centimeters.

Extension C: Determining Density (Grades 4–5)
Students determine the density of each box.

Extra Supplies

- rulers (inch or centimeter)
- scale (ounces or grams)

Extra Instructions

- Find the mass of each box.
- Determine the volume of each box (See Extension B above). If your scale is in ounces, it is best to measure in inches. If your scale is in grams, it is best to measure in centimeters.
- Determine the density using the following equation:

$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}}$$

- The result should be in either pounds per cubic inch or grams per cubic centimeter.

CROSS-CURRICULAR CONNECTIONS

FORENSIC SCIENCE

Counterfeit Coins and Jewelry
Research how law enforcement can use density to detect counterfeit coins and jewelry.

MATHEMATICS

Density of Other Objects
Extensions B and C require multiplication and division, respectively. You can further develop this by having students measure and weigh other objects to determine their volumes and densities.

LANGUAGE ARTS

Mystery Object
Have the students write a story about a mystery package. Have them reveal clues using descriptive language.

ECOLOGY

Density of Ice versus Water
Ice is less dense than water, which is why it floats. Write about how the world would be different if solid water was more dense than liquid water. (Oceans and lakes freezing from the bottom up, etc.)

RESOURCES

Great Explorations in Math and Science (GEMS), *Discovering Density*, Lawrence Hall of Science
Target level: 6th to 10th grade
This teachers' manual includes five 25- to 50-minute lessons and possible follow-up lessons. Each activity is well designed, includes detailed instructions, handouts, and data tables.

VOCABULARY

atoms: a very, very small particle that makes up all matter

density: describes how tightly packed matter (molecules, people) is in a space; dense is the adjective, density is the noun

mass: the amount of matter in an object or substance; measured by weight

matter: anything that has mass and occupies space; stuff

molecule: a group of at least two atoms held together in a definite arrangement

volume: the amount of space filled by an object or substance

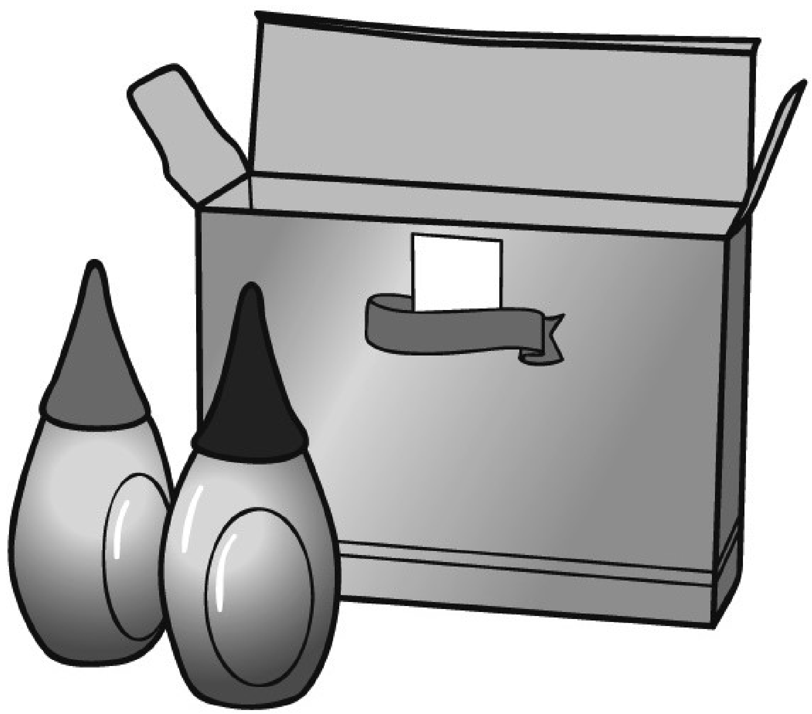
This worksheet is available online at **www.omsi.edu/k8chemistry**.

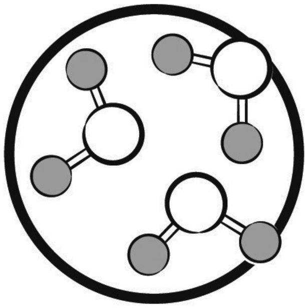
Big Things Come in Little Packages

Recommended group size: whole class

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
small boxes of the same size (approx. 4-inch cubes)	3 per class		
coins, nails, screws, bolts, or other heavy metal scraps	enough to fill box		
wooden block or scraps of wood	enough to fill box		
foam rubber, Styrofoam peanuts, or large marshmallows	enough to fill box		
gift wrapping paper and tape	enough to cover each box		
Extension A			
No additional materials needed			
Extension B			
rulers	1 per group		
Extension C			
rulers	1 per group		
scale	1 or more for class to share		





Density Rainbow

Learning Objectives: *Students investigate the concept of density.*

GRADE LEVEL

2–8

SCIENCE TOPICS

Physical Properties
Atoms and Molecules
Solutions and Mixtures

PROCESS SKILLS

Measuring
Predicting
Classifying
Inferring

GROUP SIZE

2–4

SNEAK PEAK inside …

ACTIVITY

Students stack colored liquids in a plastic drinking straw.

STUDENT SUPPLIES

see next page for more supplies

food coloring or Kool Aid™
plastic cups
sugar
clear straws, etc.…

ADVANCE PREPARATION

see next page for more details

Fill and label water bottles
Label cups of sugar, etc.…

OPTIONAL EXTRAS

DEMONSTRATION

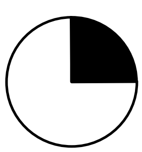
Modeling the Procedure (p. A - 15)
Make the Solutions (p. A - 15)
Classroom Density—Constant Volume (p. A - 15)
Classroom Density—Constant Mass (p. A - 16)
Sink or Float (p. A - 16)

EXTENSIONS

Mystery Solution (p. A - 23)
Calculating Density (p. A - 23)
Stack of Liquids (p. A - 24)

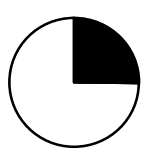
TIME REQUIRED

Advance Preparation



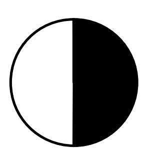
15 minutes

Set Up



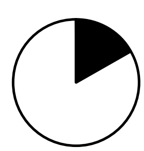
15 minutes

Activity



30 minutes

Clean Up



10 minutes

SUPPLIES

Item	Amount Needed
tall, clear, narrow plastic cups (9-oz. or 12-oz.)	5 per group
masking tape	1 roll per group
permanent markers (e.g., Sharpie™)	1 per group
granulated sugar	1 cup per group
teaspoon measure	1 per group
clear plastic drinking straws	1 per student
pop-top squeeze bottles (e.g., water or sports drink) 16-oz or larger	2 per group
food coloring (red, green, blue, and yellow) **OR** sugarless Kool Aid™ packets of the same colors	set of 4 colors per group
access to a sink (cold water works fine)	a total of 3–4 gallons of water is needed

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Sugar:

- ❑ Fill plastic cups with 1 cup of sugar for each group.
- ❑ Label plastic cups "sugar."

Water:

- ❑ Fill pop-top squeeze bottles with water, 2 for each group.
- ❑ Label bottles "water."

Color:

- ❑ Collect small bottles of food coloring (red, blue, yellow and green).
- ❑ Instead of food coloring, you can use sugarless Kool Aid™ packets. Dissolve a Kool Aid™ packet in about ¼ cup of water. Do not add sugar.

Sugar Solutions:

- Students mix their own colored sugar solutions according to the Scientific Procedure.
- To avoid messes or to streamline the activity, you may choose to prepare the solutions beforehand or as a whole class activity.

Optional Large Scale Preparation of Solutions (12 cups of water)		
Add ~30 drops of food color	Cups of sugar	Final concentration of sugar in water
Red	¼	1 tsp/cup
Blue	½	2 tsp/cup
Yellow	¾	3 tsp/cup
Green	1	4 tsp/cup

Notes and Hints

- Tall, narrow cups are best since it allows students to put their straws deeper in the sugar solutions, and it is easier to stack the different liquids in the straw.
- If clear straws are difficult to find, try a diner or small restaurant such as Denny's or Wendy's.
- Sugarless Kool Aid™ can also be used to color the solutions (two packets for 12 cups).

SETUP

For each group

- 5 tall, clear, narrow plastic cups (9-oz. or 12-oz.)
- 1 roll of masking tape
- 1 permanent marker
- 2 pop-top squeeze bottles, filled with water
- 1 plastic cup with about 1 cup of granulated white sugar
- 1 teaspoon
- clear plastic drinking straws (1 per student)

At a central location (or with the teacher)

- sponges and towels for clean up
- food coloring, set of 4 colors: red, blue, green, and yellow or sugarless Kool Aid™ packets (teacher can also pre-color the students' water—see Advance Preparation above)

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will make many sugar solutions. Each will have a different density. The less dense solutions will be able to float on the more dense solutions inside of drinking straws.

If we put 100 people in our classroom, how crowded would it be? If we put 100 people in a baseball stadium (or other large area familiar to students) how crowded would it be?
The classroom would be very crowded. The stadium would seem empty.

The Teacher Demonstration "Classroom Density" on p. A - 15 demonstrates this concept directly.

The word scientists use for crowding is density. Something that is very crowded is considered very dense. What are examples of things that are very dense or very crowded? What are examples of things that are not very dense or not very crowded?
Very dense: cities, sardines, the bedroom I share with my two brothers, the playground during recess. Not very dense: farms, the huge house my grandmother lives in by herself, the refrigerator right before we go shopping.

Molecules make up all materials. In any material, the molecules can be very crowded or spread apart. Some materials, like air, have the molecules spread far apart. Some materials, like iron, have the molecules packed close together. In general, all gases (like air) are less dense than all solids (like iron).

Misconception Alert: The "crowding" analogy for density assumes all the objects are about the same weight (e.g., people in a classroom). This analogy works when comparing collections of the same objects, like a class of people on the playground vs. the class in the classroom. However, density is really the mass per volume, so a room with just a few really, really heavy objects (like tractors) could have the same density as a room packed with people.

Some liquids or objects are more dense and sink in water; some are less dense and float on water.
What are examples of objects that sink in water?
What are examples of objects that float in water?
Float in water: wood, boat, styrofoam. Sink in water: steel, rocks, paper clips.

Can you think of liquids that float or sink in water?
Liquids that float on water are motor oil, alcohol, and vegetable oil. Liquids that sink in water are honey, corn syrup, and glue.

CAUTION: Never put lab supplies into your mouth. Even if lab supplies are food, they many be contaminated from other items in the lab.

TEACHER DEMONSTRATION

Modeling the Procedure
Especially for younger students, demonstrate how to hold liquids in a straw. Pictures are included in the procedure. Encourage students to practice filling and sealing a straw.

It is also helpful to demonstrate layering two colored sugar solutions in a straw, as some students may have difficulty interpreting the directions.

Make the Solutions
For younger students, you may wish to make all the solutions as a demonstration in front of the class. Through guided discussion, students can understand that each color of water has a different amount of sugar, and thus a different density.

- Use the recipes given in the table in Advance Preparation.

Classroom Density (Constant Volume)
This demonstration is useful for all grades and models the different sugar solutions the students create during the activity.

- Move desks or chairs to define a space in the classroom. Choose three or four students to enter the space. They represent molecules of plain water. The water molecules have a lot of room to move in the space.
- Choose three or four more students to join in the space. They represent sugar being added to the water. They make the space more dense, since the molecules are more tightly packed in the space.
- Continue to add students until the space becomes very crowded and dense. Students should understand that in a dense substance, there are many particles (corresponding to higher mass) packed in a space (volume).

Explanation

This demonstration mimics what students are doing when they create the different sugar solutions in the activity. They always have the same volume of water (represented by the space in the classroom). In each solution, they are adding a different amount of sugar (represented by the number of students). As students add more sugar, they are creating a denser solution.

Classroom Density (Constant Mass)

This demonstration is better for older students since it demonstrates a concept not seen in the lab activity.

- Move desks or chairs to define a small space in the classroom. Choose five or six students to enter the space. They should be somewhat tightly packed. This represents a dense substance.
- Pull the desks and chairs to create a slightly larger space. Encourage the students in the space to move around a little. This represents a less dense substance.
- Continue to enlarge the space until it takes up most of the classroom. Students should understand that having the same number of particles (mass) in different spaces (volume) would result in different densities.

Explanation

This represents how different substances may have different densities. A Styrofoam peanut and a paper clip may have the same mass (represented by the same number of students), but the paper clip has its molecules more tightly packed. The paper clip is denser than the Styrofoam.

Sink or Float

Use an assortment of small objects and liquids and a container of water to show how some objects float and others sink, depending on their density.

Supplies

- large jar, glass, plastic cup, or aquarium filled with water
- assortment of small objects to test (paper clip, Styrofoam, penny, cork, nail, rock, wood, golf ball, ping pong ball, pencil, eraser, marble, etc.)
- assortment of liquids to test (oil, honey, corn syrup, alcohol) Avoid liquids that will mix with the water.

Demonstration

- Show an object or liquid to students. Ask them to predict whether it will sink or float in the water.
- Test the object or liquid by dropping it into the container of water.

Explanation

Objects and liquids that are denser than water will sink in water. Objects and liquids that are less dense than water will float on water.

> **Misconception Alert:** Many students may make a connection that an item will float if it has air, or that air is necessary to make an object float in water. Using oil or alcohol, which have no air and which float in water, can help students to understand that air is not necessary for something to float.

> **Misconception Alert:** Substances like steel and concrete sink in water, but they can be used to make boats that float on water. This is because the material is spread apart to take up a larger space. This makes the overall structure less dense and it floats.

CLASSROOM ACTIVITY

Have students work in groups of 2–4 and follow the Scientific Procedure, starting on page A - 27. Below are suggestions to help the teacher facilitate the activity.

NOTES

This handout is on p. A - 27.

Density Rainbow

SCIENTIFIC PROCEDURE

1. Label four cups from #1 to #4.
   Label the fifth cup "waste."

2. Half fill cups #1 to #4 with water.
   Add sugar to each cup according to the chart.

Cup	Sugar (spoonfuls)	Color (4 drops)
1	1	red
2	2	blue
3	3	yellow
4	4	green

3. Add water to cups #1 to #4 to look like the picture.
   Color the water in each cup according to the chart.

Running Suggestions

- Students can stir their solutions with the straw to help the sugar dissolve faster. Warm water will dissolve the sugar faster but is not necessary.
- Monitor students to make certain that they have the same amount of water in each cup after they dissolve the sugar.
- To avoid extra mess, you can pre-color the solutions and let the students add sugar. Students will need to trade colored solutions between groups to get all the colors they need. You may want to show students that even though the water is different colors, it all has the same density before the sugar is added.
- Encourage students to lift their fingers SLOWLY off of the straw while it's under water; the layers are less likely to mix that way. **Also make certain that students are putting the straw lower in each successive liquid.**
- Use narrow 8-oz or 12-oz cups if possible. This will allow the straws to be inserted deeper in the water so students can fit all four colors in their straws.
- If students have difficulty seeing the layers of colors in their straw, it may help to hold the straw against a white background.

Ongoing Assessment

- For younger students, ask them to draw and color pictures of the liquids as they layer in the straw. You can also use the data sheet provided on page A - 32.
- Why is it important to have the same amount of water in all the cups? *We want to pack the different masses of sugar into the same volume in the cups, so their densities are easier to compare*.
- What happens if you add the solutions in the reverse order? *This will put a more dense liquid on top of a less dense liquid. They will mix as they try to trade places.*
- What will happen if you turn the straw upside down? *A more dense liquid would be on top of the less dense liquid. They will mix as they try to trade places.*
- How could you find the density of an unknown solution? *Layer the unknown solution over or under those that are known. If it is less dense than the other solution, it will float. If it is more dense than the other solution, it will sink.*

Safety and Disposal Information

- All liquids can be poured down the sink or saved in a large container for later disposal.
- Cups and straws can be rinsed and re-used or thrown away.

CAUTION: Never put lab supplies into your mouth. Even if lab supplies are food items, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Which liquid is most dense? (Which sank?) Why?
The one with the most sugar. This liquid had the most mass packed into a space.

Which liquid is least dense? (Which floated on all the other liquids?) Why?
The one with no sugar, or the one with the least sugar. This liquid had the least mass packed into a space.

Choose questions that are appropriate for your classroom.

What other materials could you do this experiment with?
Oil, corn syrup, salt water, alcohol, etc.

Will the layers stay separate, or will they eventually mix?
The layers will eventually mix, because the sugar molecules will travel to other layers, so the solution will eventually have the same density all the way through.

The colored liquids each have a different amount of sugar dissolved in a cup of water. When students start with the less dense liquid on top of the more dense liquid, they don't mix. When students add liquids out of order, a less dense liquid is below a more dense liquid. The less dense liquid wants to float, and the more dense liquid wants to sink. So the two liquids mix as they try to switch places.

EXPLANATION

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

In this activity, students create different solutions of sugar water. They compare the ability of these liquids to sink or float on each other.

BACKGROUND FOR ALL GRADES

All matter is made of **atoms.** Atoms combine to make **molecules**. Atoms and molecules are too small to see, but, together, they make up all substances. To find out how much matter is in a substance, scientists weigh the substance to determine its **mass**. The more matter a substance contains, the more mass it has.

Density

When sugar **dissolves** in water, the molecules of sugar separate from each other and become completely surrounded by the water molecules. When more sugar dissolves in water, there is more matter packed into the same space. This makes the liquid denser.

In this activity, students create different solutions, each with a different amount of sugar in the same amount of water. As more sugar is added, more matter is squeezed into the same space. This increase in matter in a given space causes an increase in **density**. Density is a measure of the amount of matter packed into a space. Density increases when the amount of matter goes up (Figure 1) or when the space it is packed in goes down (Figure 2). In this exercise, students increase density by packing in more matter (i.e., sugar).

More molecules → More packing → More dense

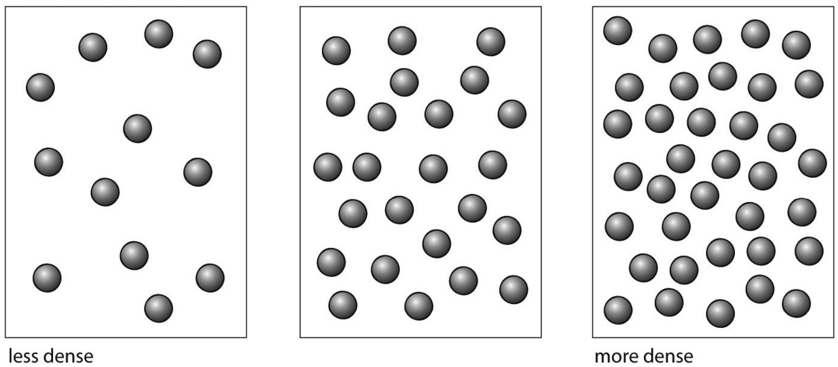


Figure 1. Each square is the same size, but has an increasing number of molecules (12, 24, and 36 from left to right).

Loosely packed spaces are less dense than highly packed spaces.

Less space → More packing → More dense

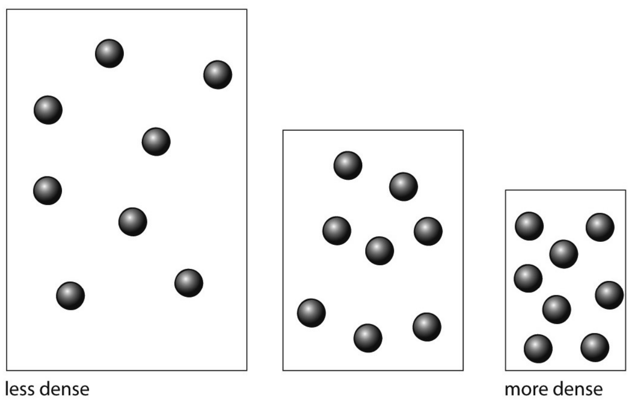


Figure 2. These rectangles all contain 8 molecules, but they are packed into smaller and smaller spaces.

As the molecules are packed more closely together, the rectangle becomes more dense.

Sink or Float?

The concept of density explains why things sink or float in water. If a solid (like wood) is less dense than water, it will float on the water—regardless of the weight. For instance, pianos float on water, even though they are very heavy, because they are less dense. On the other hand, solids that are more dense (like metals) will sink in water. Even a piece of metal as light as a dime will sink in water because the metal is more dense.

Liquids work the same way. Those that are less dense will float on top of those that are more dense. For example, oil floats on water because oil molecules are not as tightly packed (i.e., not as dense) as water molecules. Just as with pianos and dimes, the total amount of the water and oil doesn't matter—if someone pours a can of oil on the bottom of a swimming pool and then fills the pool with water, the oil will still float on top.

In the same way, the molecules in honey are more tightly packed than the molecules in water, so honey will sink in water. (It eventually dissolves in water, though, and becomes evenly dispersed throughout the solution.)

Population Density

Population scientists and **demographers** describe the population density of cities, states, or countries. These scientists use the number of people living in a square mile of an area. Higher density urban areas have a larger number of people per square mile; lower density rural areas have a smaller number of people per square mile. The people are more tightly packed in densely populated areas.

EXTRA BACKGROUND FOR GRADES 5–8

Mathematics of Density

In addition to these general descriptions about density, it is possible to measure and then calculate a substance's density. To find a numerical value for the density of a substance, we measure the **mass** of the substance (how much matter it contains) and the **volume** of the substance (how much space it fills).

Dividing the mass by the volume gives the **density** of the substance:

$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}}$$

Using the metric system, mass can be measured using grams (g) or kilograms (kg). Volume is measured using milliliters (mL) or liters (L). Therefore density is expressed as a ratio of mass to volume: for example, grams per milliliter (g/mL) or kilograms per liter (kg/L).

We can apply this same method of measurement to the Figure 1 in the previous section to give numerical descriptions for their density. Let's assume each molecule weighs 1 gram and that each box is 1 liter (not true, but it makes for easy calculations). For each picture, the density is calculated by taking the mass (12 grams) and dividing by the volume (1 liter). For example, the first box in Figure 1 has a density of 12 grams per liter.

A Density Surprise

Because density is defined as mass per space, some "less packed" arrangements of molecules can actually be as dense as more tightly packed arrangements, as long as the individual molecules are each much heavier. Consider Figure 3 that shows three boxes with equal density. Because the molecules are heavier in the first box, it has the same density as the more packed arrangement of the third box.

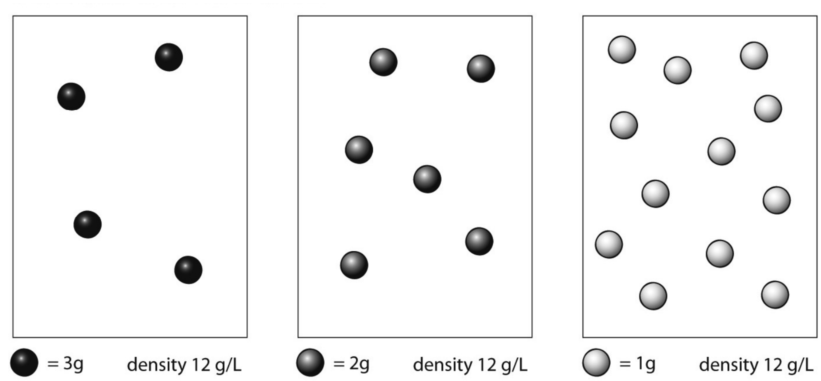


Figure 3. Each box has the same volume (1 L) and contains the same mass (12 g), so they each have the same density (12 g/L).

Density of Water
The density of water is 1 gram per milliliter (1 g/mL). This means that one milliliter of water weighs one gram. Substances that have a density greater than water (greater than 1g/mL) will sink in water. Substances that have a density less than water (less than 1g/mL) will float on water.

An interesting note is that the milliliter and the gram are actually defined by using the volume and density of water. A cube of water that is one centimeter on each edge is one cubic centimeter (cc) and equal to one milliliter (mL). This volume of water is defined to have a mass of one gram (g).

EXTENSIONS

Extension A: Mystery Solution
Students identify the density of an unknown solution of sugar water.

Extra Supplies
- large bowl or plastic gallon jug—1 per class
- extra pop-top squeeze bottle—1 per group
- extra plastic cup—1 per group

Extra Instructions
- To make the mystery sugar water mixture, fill the large bowl or plastic gallon jugs with 1 cup of water per student group. Add 1 to 4 spoonfuls of sugar (you choose) for each cup of water. Mix well. Fill the extra pop-top water bottles with the mystery solution.
- Give student groups a bottle of the mystery solution and an extra plastic cup.
- Ask students to use their straws and the other solutions to determine the density of the mystery solution. Students should pair this solution with their known solutions to see when their mystery solution floats and when it sinks.

Explanation

By comparing solutions in straws, students should be able to determine that the mystery solution is more dense than some solutions and less dense than others. It may not be possible to determine the exact density of the mystery solution, but students should be able to find a range of density for the mystery solution.

Extension B: Calculating Density
Students will measure the mass and volumes of the colored liquids in order to calculate the exact density of each. To do so, they will measure out certain volumes of the liquids and then weigh them. The ratio of the mass to the volume of the liquid is the density.

Extra Supplies

- scale or balance—1 per group
- graduated cylinder or other measuring container—1 per group or class
- extra plastic cups or other weighing containers—1 per group

Extra Instructions

- Use the Scientific Procedure sheet and Data Sheet for this extension.
- Students must carefully measure both volume and mass.
- After students have determined the density of each solution, they should verify that it matches with their observations in the general procedure.
- If they have also completed Extension A, they should verify that their measurements confirm their observations of the mystery solution.

Explanation

The density of any substance can be determined using the formula:

$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}}$$

Denser solutions have a larger mass squeezed into a smaller volume. When mass is divided by the volume, the value for density is larger. The solutions that are less dense have a smaller mass in a larger volume. In this case, the value for density will be smaller.

Extension C: Stack of Liquids

Using the methods from Extension B, the density of any liquid can be determined. Give students the following challenge: Find three household liquids that can be stacked in a cup according to their density.

Extra Supplies

- one or more of a variety of liquids: oil, vinegar, honey, ketchup, glue, dish soap, rubbing alcohol, corn syrup, molasses, water, salt water, sugar water—½ cup per group, or less, depending on setup
- plastic cups—3 per liquid, or more, depending on setup
- scales or balances—1 per group
- graduated cylinders or other measuring devices—1 per group

Extra Instructions

- Use the Scientific Procedure sheet and Data Sheet for this extension to have students measure the volume and then measure the mass of each liquid.
- After finding the density of the liquids, students should sort the liquids in order from most dense to least dense.
- Have the students test their predictions/calculations by carefully pouring some of each liquid into a cup so that all the liquids stack.

- **Hint:** If students tilt the cup and run the liquid down the side, it is easier to create the layers.
- **Hint:** Rather than have all students share stock bottles, halfway fill plastic cups with each of the variety of liquids. Each plastic cup should have ¼ to ½ cup of liquid. This allows for more students to have access to any liquid.

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES

Population Density

Use the census data links provided to get population information. From this data, calculate the population density of cities, towns and states.

PHYSICS

Buoyancy

Have students design boats from clay or aluminum foil. (Both objects are denser than water and normally sink.) By increasing the volume of the clay or foil they can create a vessel that will float or hold cargo. Things that float have positive buoyancy; things that sink have negative buoyancy

Flinkers

Supply students with an array of items and challenge them to make an object that has an equal density to water. This object doesn't float, doesn't sink, so it "flinks." Flinkers are things that have neutral buoyancy. Students can attach two objects together, one that sinks and one that floats, and see if they negate each other. Stick paper clips into a cork, attach a balloon to a washer, or glue Styrofoam to a rock.

OCEANOGRAPHY METEOROLOGY

Ocean Currents

Temperature differences also cause differences in density. When water is cold, the water molecules are more tightly packed, so it sinks. Since warmer water is less dense, it will rise. It is this property that creates the ocean currents and determines weather patterns all over the globe.

Lava Lamp

A good demonstration of how density changes with temperature can be seen in a lava lamp. These lamps have two liquids: oil and wax. The wax floats and sinks in the oil as it changes density. When the wax is at the bottom of the lamp near the bulb, it heats up and rises. When it reaches the top of the lamp, it cools down and sinks.

RESOURCES

Web—http://antwrp.gsfc.nasa.gov/apod/ap001127.html
This satellite picture of the Earth at night shows how people are distributed around the world. The lit areas are densely populated cities.

Web—http://www.census.gov/population/www/censusdata/density.html
Many links to population data of cities and states. Some have calculated density, some have data for calculation.

Web—http://www.hometrainingtools.com/articles/exploring-liquid-density-newsletter.html
More activities for studying the density of liquids.

Web—http://www.exploratorium.edu/climate/primer/hydro-p.html
Good article explaining ocean currents and their role in climate change. Shows pictures of ocean currents and describes how salt concentration and temperature play a role.

Great Explorations in Math and Science (GEMS), *Discovering Density*, Lawrence Hall of Science
Target level: 6th to 10th grade
This teachers' manual includes five 25- to 50-minute lessons and possible follow-up lessons. Each activity is well designed and includes detailed instructions, handouts, and data tables.

VOCABULARY

atom: a very, very small particle that makes up all matter

demographer: a scientist who studies the characteristics of human populations, such as size, growth, density, distribution, and vital statistics

density: describes how tightly packed matter (molecules, people) is in a space; dense is the adjective, density is the noun

dissolve: when the molecules of one substance separate and become completely surrounded by the molecules of another substance

dots per inch (dpi): a measure of digital picture resolution; the number of dots that fit in a line one inch long

mass: the amount of matter in an object or substance; measured by weight

matter: anything that has mass and occupies space; stuff

molecule: a group of at least two atoms held together in a definite arrangement

population scientist: a scientist who studies the growth and density of populations

volume: the amount of space filled by an object or substance

Density Rainbow

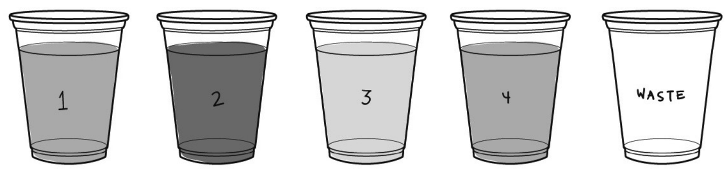
SCIENTIFIC PROCEDURE

1. Label four cups from #1 to #4.
   Label the fifth cup "waste."

2. Half fill cups #1 to #4 with water.
   Add sugar to each cup according to the chart.

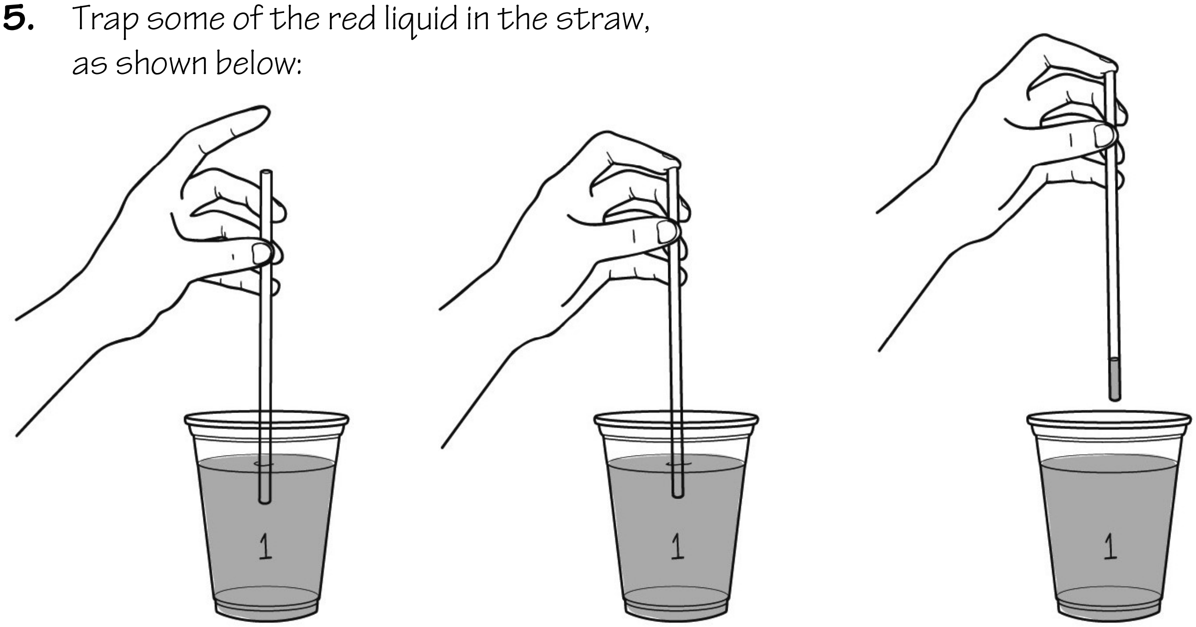
Cup	Sugar (spoonfuls)	Color (4 drops)
1	1	red
2	2	blue
3	3	yellow
4	4	green

3. Add water to cups #1 to #4 to look like the picture.
   Color the water in each cup according to the chart.



4. Stir the water until all of the sugar has dissolved.

5. Trap some of the red liquid in the straw, as shown below:

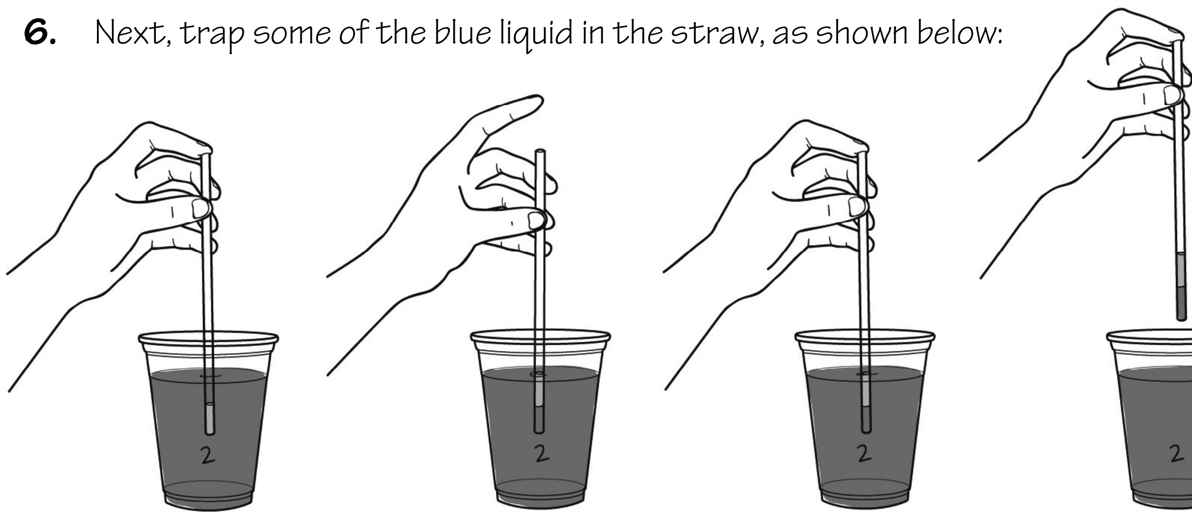


Dip the straw in about ½ inch.

Put your finger over the top of the straw …

… and lift the straw out of the cup. Keep your finger on the straw!

6. Next, trap some of the blue liquid in the straw, as shown below:



Keep your finger on the straw and lower it into the next cup.	Take your finger off the top of the straw to let the other solution in.	Put your finger back on the straw …	… and lift the straw out of the cup.

- *What happened? Did the colors mix or stay separate?*

7. Continue this procedure with the rest of the cups of colored water. **Remember that you must put the straw lower in the water than the level of liquids in the straw, or else no more water will enter the straw.**
   - *What happened? Did the colors mix or stay separate?*

8. Empty your straw into the waste cup.

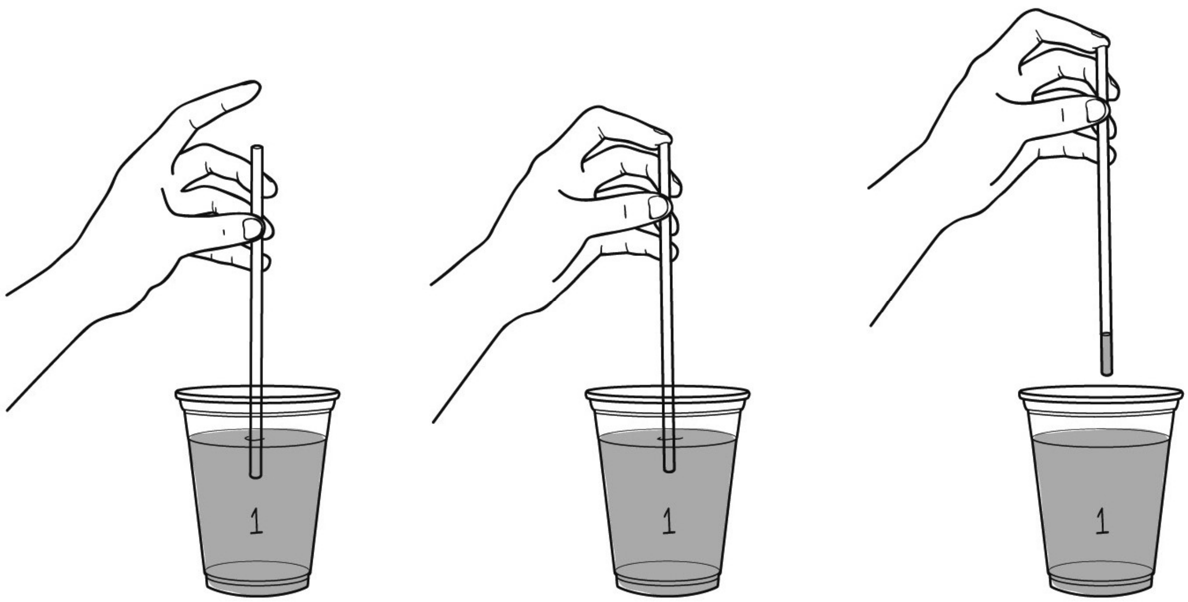
9. Try adding the colors in a different order. Experiment with many different orders.
   - *What order makes the colors mix the most?*

   - *What order makes each color stay separate?*

10. Clean up your area.
    - *Follow your teacher's directions.*

Making a Density Rainbow

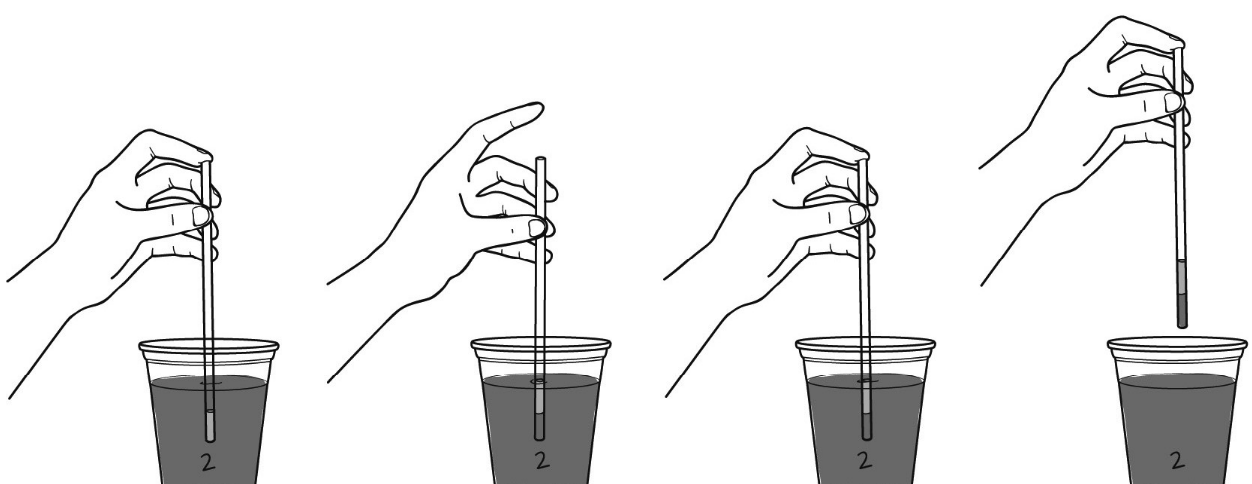
Close up of straw procedure



Dip the straw in about ½ inch.

Put your finger over the top of the straw …

… and lift the straw out of the cup.



Keep your finger on the straw and lower it into the next cup.

Take your finger off the top of the straw to let the other solution in.

Put your finger back on the straw …

… and lift the straw out of the cup.

Density Rainbow

SCIENTIFIC PROCEDURE
for EXTENSION B or C

1. Choose a liquid. Write the name of the liquid in column A on the Data Sheet.

2. Measure the mass of an empty container using a scale or balance. Record the mass in column B on the Data Sheet. Remember to write the correct units with your measure.

3. Carefully measure at least a tablespoon (15 ml) of the liquid. Record the volume of your liquid in column E on the Data Sheet.

   Remember to write your units with your measure.

4. Add the liquid to the container you just weighed.

5. Record the mass of both the liquid and the container in column C on the data sheet.

6. Find the mass of the liquid. To do this, subtract the value in column B from the value in column C on the Data Sheet. That is:

   mass of container and liquid - mass of container = mass of liquid

   Remember to write units with your value in Column D.

7. Calculate the density of the liquid. To do this, divide the mass of the liquid (column D) by the volume of the liquid (column E). That is:

$$\text{density} = \frac{\text{mass of liquid}}{\text{volume of liquid}}$$

   Remember to write units with your value in Column F.

8. Repeat steps 1 through 6 for all your liquids, recording the values on the Data Sheet.

9. Clean up your area.
   - Follow your teacher's directions.

Density Rainbow

DATA SHEET
for EXTENSIONS B or C

A	B	C	D	E	F
name of liquid	mass of container	mass of container and liquid	mass of liquid	volume of liquid	density

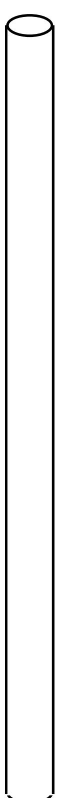
Density Rainbow

DATA SHEET

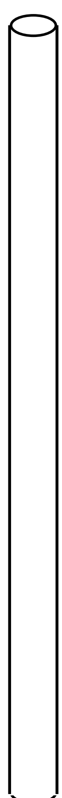
Color a picture of your straw each time you fill it with liquids.
Beside each picture, list the order you added the colors to the straw.

- Did they stay in the order you added them?

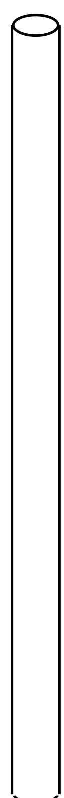
- Did they mix together?



Notes:



Notes:



Notes:

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Density Rainbow

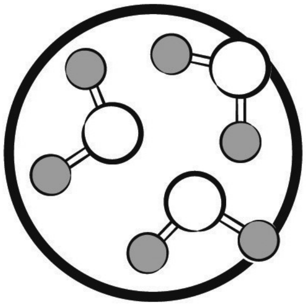
Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
tall, clear, narrow plastic cups (9 oz. or 12 oz.)	6 per group		
masking tape	1 roll per group		
permanent markers (e.g., Sharpie™)	1 per group		
granulated sugar	1 cup per group		
teaspoon measure	1 per group		
clear plastic drinking straws	1 per student		
pop-top squeeze bottles (e.g., water or sports drink)	2 per group		
food coloring (red, green, blue, and yellow) OR sugarless Kool Aid™ packets of same colors	set of 4 colors per group		
access to a sink	a total of 3–4 gallons of water is needed		
towels and sponges	several for class		
Extension A			
large bowl, pitcher, or plastic gallon jug	1 per class		
extra pop-top squeeze bottle	1 per group		
extra plastic cup	1 per group		
Extension B			
scales or balances	1 per group		
graduated cylinder or other measuring container	1 per group		
extra plastic cups or other weighing containers	5 to 7 per group		

Supply Worksheet continues on next page.

Extension C			
variety of liquids: oil, vinegar, honey, ketchup, glue, dish soap, rubbing alcohol, corn syrup, molasses, water, salt water, sugar water	1–2 cups of each liquid per class		
plastic cups (optional)	2 or 3 per liquid		
scale or balance	1 per group		
graduated cylinder or other measuring container	1 per group		
extra plastic cups or other weighing containers	5 to 7 per group		
Teacher Demonstration			
Sink or Float			
large jar, glass, plastic cup, or aquarium filled with water	1 per class		
assortment of small objects to test: paper clip, Styrofoam, penny, cork, nail, rock, wood, golf ball, ping pong ball, pencil, eraser, marble, etc.	1–2 of each item		
assortment of liquids to test: oil, honey, corn syrup, alcohol, ketchup	¼ cup of each liquid		



Inner Space

Learning Objectives: *Investigate the properties of molecules, and discuss the use of models in science.*

GRADE LEVEL

2–8

SCIENCE TOPICS

Atoms and Molecules
Techniques

PROCESS SKILLS

Predicting
Making Models
Explaining

GROUP SIZE

3–4

SNEAK PEAK inside …

ACTIVITY

Students completely fill cups with marbles or water. Then they discover that there is still room to add salt or sand between the marbles or water molecules.

STUDENT SUPPLIES

see next page for more supplies

plastic cups
marbles
salt
sand
cafeteria trays, etc.…

ADVANCE PREPARATION

see next page for more details

Fill water containers.
Prepare cups of marbles, sand, and salt.
etc.…

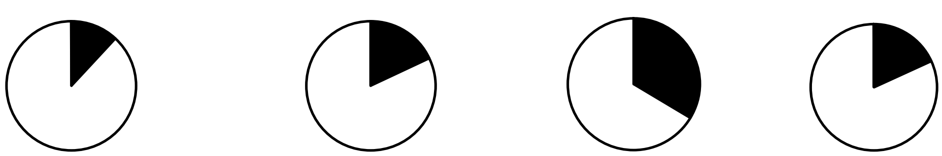
OPTIONAL EXTRAS

DEMONSTRATION
Odors Aloft (p. A - 38)

EXTENSIONS
Inquiry Opportunity (p. A - 43)
Density of Saltwater and Plain Water (p. A - 43)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
5 minutes	10 minutes	20 minutes	10 minutes



SUPPLIES

Item	Amount Needed
plastic cups, 8-oz. or smaller	5 per group
water	1 cup per group
pop-top squeeze bottles (e.g., water or sport drink) 16 oz. or larger	1 per group
marbles (or other small, spherical objects)	1 cup per group
large jar or margarine tub, 2- to 4-cup capacity	1 per 2–3 groups
salt	½ cup per group
sand	½ cup per group
plastic spoons **OR** measuring teaspoons	2 per group
cafeteria trays	1 per group
coffee filters	several for class to share
strainer	1 or more for class to share
bowl	1 or more for class to share

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Water:
- Fill pop-top squeeze bottles with about 1 cup of water.
- Label bottles with "water."

Marbles:
- Fill large jars or margarine tubs with marbles.
- If marbles are unavailable, buttons or large rounded rocks could work.
- Spherical objects are best since they leave the most empty space in the cup.

Sand:
- Fill plastic cups with about ½ cup of sand.
- Label cups with "sand."

Salt:
- Fill plastic cups with about ½ cup of salt.
- Label cups with "salt."

Notes and Hints

- It does not matter whether you use plastic spoons or measuring spoons for this activity. However, to compare results between groups, it is important that all plastic spoons are the same size.
- Cafeteria trays help to contain spilled water in this activity.

SETUP

For each group

- pop-top squeeze bottle with water
- ½ cup salt in a plastic cup
- ½ cup sand in a plastic cup
- 3 plastic cups
- 1–2 plastic spoons
- cafeteria tray

At a central location (or with the teacher)

- sponges and towels for clean up
- large containers of marbles
- coffee filters, strainer, and large bowl or tub.

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

Depending on the background knowledge of your students, you may wish to start with the demonstration and discuss the properties of molecules.

What are the different states of matter?
Sold, liquid, gas.

How are molecules arranged in all of these states?
In a solid, molecules are packed together in a regular way. They vibrate in place. In a liquid, molecules are close together, and they move and jostle one another constantly. In a gas, molecules are spread far apart and move at high speed.

Notice that in all states of matter, the molecules of a substance stay together, but there are still spaces between molecules. In this activity, students will study this inner space between molecules.

For this activity, we will be filling a cup so that it is full of water. How shall we decide when the cup is "full"?
Take suggestions from students. As a class, agree to a definition of what a "full" cup of water looks like. It may be level with the top of the cup, water added until it is bulging over, or somewhere in between.

For this activity, we will be counting full spoonfuls of sand and salt. How shall we measure a "full" spoonful?
Take suggestions from students. As a class, agree to a definition of what a "full" spoonful looks like. It may be leveled off using a pencil, or it may be as much as you can pile on, or somewhere in between.

It is very important that the class agree to a definition of "full" for both the water in the cup and the sand and salt in the spoon. This assists in comparing results. Also, and perhaps more importantly, scientists have standard measures they use, and defining measures as a class is good scientific practice.

TEACHER DEMONSTRATION

Odors Aloft
As an introduction to the properties of molecules, prepare a balloon for students to observe using the sense of smell.

This is a small part of the full activity **Odors Aloft**.

Supplies

- 2–3 balloons
- peppermint extract (Note: Any extract will work, but peppermint seems to work best. It is a very recognizable smell and diffuses through the balloon very quickly.)
- straw (for inserting extract into balloon)

How to Insert Extract (Figure 1)

1. Collect some peppermint extract (less than 1 tsp.) with a straw. Use your finger on the top of the straw to trap the liquid in the bottom.
2. Insert the straw into the mouth of the balloon.
3. Release the contents into the balloon.
4. Remove the straw.
5. Blow up the balloon and tie it closed. Be careful not to let the balloon deflate until it is tied closed.

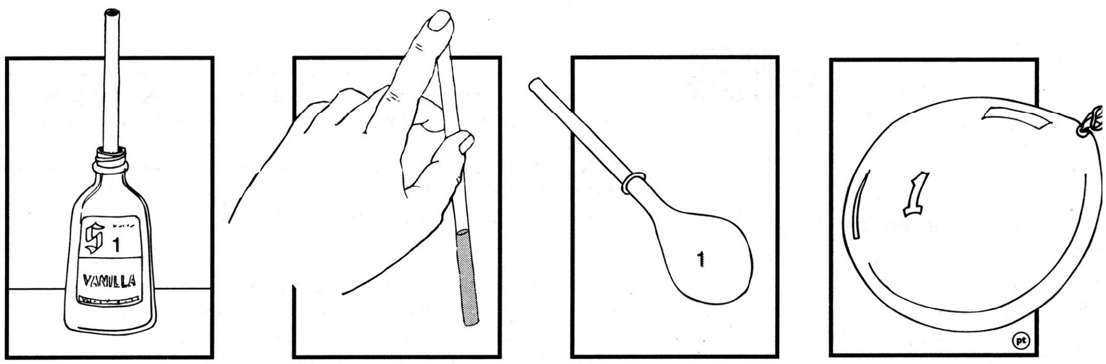


Figure 1. Steps to insert extract into a balloon.

Demonstration

- In front of the students, insert peppermint extract into a balloon. (See pictures and instructions above.)
- Inflate the balloon and tie it.
- Repeat with another 1 or 2 balloons.
- Discuss the following with the students:
  - Where is the peppermint extract? (*It is inside the balloon.*)
  - Is there a way for it to get out of the balloon? (*No, the balloon holds it inside. Yes, there are small holes in the balloon surface that we can't see.*)
  - How could we find out if any peppermint extract is escaping? (*We would be able to smell it!*)
- Pass the balloons around the class and invite students to smell them. Students should be able to smell peppermint extract through the balloon.

Explanation

We smell odors when the molecules of a substance reach our nose. Even though the balloon is solid, the molecules in the peppermint extract were able to pass through the balloon to our nose. This is because when molecules are together to make a material, there is still space between the molecules that allow smaller molecules to pass through.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page A - 45, working in groups of 3–4. Below are suggestions to help the teacher facilitate the activity.

NOTES

Inner Space

SCIENTIFIC PROCEDURE

This handout is on p. A - 45.

1. Label three cups "marbles," "salt water," and "sand water."
2. Completely fill the cup labeled "marbles" with marbles.
   - How do you know the cup is full?
   - Do you think you could add sand to this cup? Where would the sand go if you added it?

3. Add sand to the cup full of marbles.
   - How many spoonfuls of sand can you add to the marbles?

Running Suggestions

- Students should record their observations as the procedure prompts them. If a question comes before a step, students should record their answer BEFORE doing the step.
- As described in Introducing the Activity, the class needs to decide what "full" means when filling their cups with water. Does full mean level on the top or bulging over so no more will fit? This activity will work both ways but works best if students choose full to mean bulging over. Students tend to fill their cups about the same amount when they all try to "overfill" them to bulging. Also, very full cups of water fill more quickly with salt and sand.
- Water will spill in this activity. Tell students to do their experiments on the cafeteria tray.
- Tell students to put their sand water and saltwater cups in a secure place before they add water. Adding so much water makes the cups impossible to move without spilling.

Ongoing Assessment

- How do your results compare to your predictions?
- Do you think the same thing will happen if you repeat the experiment? Try it and see.

Safety and Disposal

- Students should pour sand water through a coffee filter or paper towel and strainer to separate the sand. Once the sand is collected, it can be reused.
- Salt water can go down the sink.

Caution: Do not pour sand down the sink. It may clog the drain.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Did the experiment turn out as you predicted?
Answers will vary. Most students will be surprised at how many spoonfuls of salt will fit into the a full cup of water.

How many spoonfuls of sand were you able to add to your cup of water? How many spoonfuls of salt were you able to add?
Collect information from the students.

Where did the salt go? Why did more salt fit in the water than sand?
Even though the cup appeared "full," there was still space between the molecules of water. Both the salt and sand fit in between these spaces, but the salt fit better because it dissolved in the water. The salt molecules break up into parts, which fit easily into the spaces between the water molecules. The sand could not dissolve, so it could not fit as well into those spaces.

For more information about how salt dissolves in water, see the Explanation section of **Salting Out**.

If the marbles represented water molecules, where was the salt fitting?
The salt fit between the water molecules, just like it would fit between the marbles.

Are marbles a good representation of molecules? Why or why not?
Yes. Marbles fit together in certain patterns just like molecules fit together in certain patterns. There is space between marbles just like there is space between molecules.
No. Marbles leave a lot of space between them and molecules don't leave as much space. Marbles are spherical and not all molecules are spherical. Also, molecules move, and marbles don't.

EXPLANATION

By adding salt to an already full cup of water, students discovered that it is possible to fit salt molecules between the molecules of water. This inner space allowed an already full cup of water to fit more material.

Properties of Matter
All matter is made up of **atoms**. **Atoms** bond together to make **molecules**. Inside and between molecules and atoms are empty spaces. Molecules are farthest apart in a gas, but, even in a liquid state, molecules have plenty of space between them.

Fitting into the Inner Space
Table salt, also called sodium chloride (NaCl), is made up of equal parts of two small atoms called sodium (Na) and chlorine (Cl). In water, the sodium and chlorine atoms separate from each other and become surrounded by water molecules. In this process, the salt **dissolves** in the water.

The salt fills the spaces between the water molecules. This allows more matter to fit in the cup even though it is already full of water. This means that when we compare a full cup of water to a full cup of saltwater, the saltwater will have more matter in it, and it will weigh more. Because saltwater has more matter in the same volume when compared to plain water, saltwater is more **dense** than plain water.

For a more detailed discussion of density, read the explanation section of **Big Things Come in Little Packages**.

Sand, or **silica** (silicon dioxide), cannot break up to fit into the spaces between water molecules. Sand does not dissolve in water. For this reason, students cannot add as many spoonfuls of sand to their full water cups as they can add salt.

Surface Tension of Water
Water molecules have a strong attractive force to one another. This attractive force, known as **surface tension**, allows the water to bulge on the top of the cup before spilling over.

EXTENSIONS

Extension A: Inquiry Opportunity
Repeat the experiment and substitute different ingredients for the ones used in the main activity.

- Instead of water, try vinegar, rubbing alcohol, or vegetable oil
- Instead of salt, try sugar, Epsom salt, or powdered milk
- Try changing the temperature of the liquid used in the experiment

CAUTION: Rubbing alcohol (70% isopropyl alcohol) is flammable and poisonous. Keep away from heat and open flames.

Extension B: Density of Saltwater and Plain Water
Students measure and compare the densities of saltwater and plain water.

Extra Supplies

- scale or balance
- measuring cups

Extra Instructions

- Add salt to ½ cup of water and mix until no more salt will dissolve in the water.
- Measure ¼ cup of the saltwater and pour it into a plastic cup.
- Weigh the container with the salt water in it. Record the weight of the container with saltwater.
- Empty and dry the plastic cup. Save it for the next step.
- Measure ¼ cup of plain water and pour it in the plastic cup.
- Weigh the cup with the plain water in it. Record the weight of the container with plain water.
- Which weighs more, the cup with saltwater or the cup with plain water? Why?

Explanation

Even though both the saltwater and the plain water take up the same amount of space, the saltwater weighs more. This is because the saltwater has salt dissolved in the water, filling up some of the space between the water molecules. When two substances take up the same space, but have different weights, the one that weighs more is more dense.

For a more detailed examination of the comparative densities of liquids, try the activity **Density Rainbow**.

CROSS-CURRICULAR CONNECTIONS

BIOLOGY — **Importance of Salt**

Discuss how saltwater is necessary for many living things. For example, human blood is about 1% salt, and the ocean environment is about 3.5% salt. If the salt content is too high, most living things cannot survive. That is why salt is used to preserve food and prevent growth of microorganisms on, e.g., bacon, pickles, etc.

PHYSICS — **Surface Tension**

Discuss the surface tension that allowed the glass to fill "beyond full"—to bulge over the top of the glass.

RESOURCES

Web – http://www.middleschoolscience.com/suface.htm

The general website features many science lesson plans. This lesson plan (under Chemistry) explores the surface tension of water by counting how many drops of water will fit on a penny. The website address really does have "surface" misspelled.

VOCABULARY

atoms: a very, very small particle that makes up all matter

dense: describes how tightly packed molecules are in a substance

dissolve: when the molecules of a substance separate and become completely surrounded by the molecules of another substance

molecules: a group of at least two atoms held together in a definite arrangement

silica: silicon dioxide; forms the mineral quartz, which is the main ingredient in sand

surface tension: an elastic-like force in liquids caused by the molecules at the surface being attracted to one another

Inner Space

SCIENTIFIC PROCEDURE

1. Label three cups "marbles," "saltwater," and "sand water."

2. Completely fill the cup labeled "marbles" with marbles.
   - *How do you know the cup is full?*
   - *Do you think you could add sand to this cup? Where would the sand go if you added it?*

3. Add sand to the cup full of marbles.
   - *How many spoonfuls of sand can you add to the marbles?*
   - *Where did the sand go?*

4. Completely fill the cups labeled "saltwater" and "sand water" with water.
   - *How do you know the cups are full?*
   - *How are these cups full of water similar to the cup full of marbles?*

5. In the next step, you will add sand to the "sand water" cup until the water overflows.
   - **Predict:** *How many spoonfuls of sand do you think you can add?*

6. Carefully add 1 spoonful of sand to the "sand water" cup. Count and add more spoonfuls of sand.

- *How many spoonfuls of sand could you add to the water?*

- *Where did the sand go?*

7. In the next step, you will add salt to the "saltwater" cup until the water overflows.

- **Predict:** *How many spoonfuls of sand do you think you can add?*

8. Now add one tablespoon of salt to the "saltwater" cup. Count and add more spoonfuls of salt.

- *How many spoonfuls of salt could you add to the water?*

- *Where did the salt go?*

9. Clean up your area.

- *Follow your teacher's directions.*

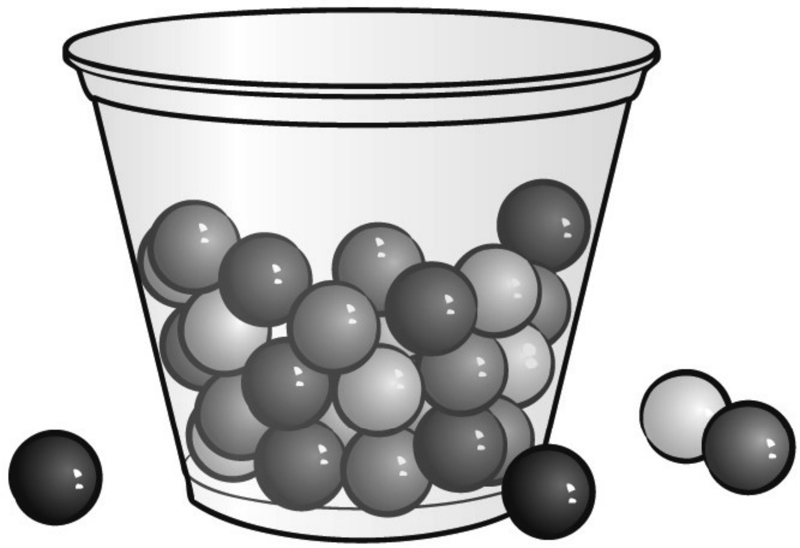
This worksheet is available online at **www.omsi.edu/k8chemistry.**

Inner Space

Recommended group size: 3–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
plastic cups, 8-oz. or smaller	5 per group		
water	2 cups per group		
pop-top squeeze bottles (e.g., water or sport drink) 16 oz.	1 per group		
marbles (or other small, spherical objects)	1 cup per group		
large jar or margarine tub, 2- to 4-cup capacity	1 per 2–3 groups		
salt	½ cup per group		
sand	½ cup per group		
plastic spoons **OR** measuring teaspoons	2 per group		
cafeteria trays	1 per group		
coffee filters, strainer, and bowl (or plastic tub)	1 set for class		
Extension A			
alternate liquids: vinegar, alcohol, or vegetable oil	2 cups each liquid per group		
alternate solids: sugar, Epsom salt, or powdered milk	½ cup each solid per group		
hot water or cold water	2 cups each temperature per group		
Extension B			
scale or balance	1 or more for class to share		
measuring cups	1 set per group		
Teacher Demonstration			
Odors Aloft			
balloons	2–3 per class		
peppermint extract	2–3 tsp. per class		
straw	1 per class		



Matter of Degree

Learning Objectives: *Learn about exothermic reactions (that release energy) and endothermic reactions (that absorb energy).*

GRADE LEVEL

K–8

SCIENCE TOPICS

Physical Properties
Solutions and Mixtures
Chemical Reactions

PROCESS SKILLS

Comparing and Contrasting
Measuring
Organizing Data

GROUP SIZE

2–4

SNEAK PEAK inside …

ACTIVITY

Mixing water with different white powders in plastic sandwich bags makes them hot and cold.

STUDENT SUPPLIES

see next page for more supplies

Epsom salts
laundry detergent
sealing plastic bags
pop-top squeeze bottles, etc.…

ADVANCE PREPARATION

see next page for more details

Fill cups with powders
Fill bottles with water, etc.…

OPTIONAL EXTRAS

DEMONSTRATION
Hot and Cold Packs (p. A - 52)

EXTENSIONS
Test Other Powders (p. A - 57)
Measure Temperature Change (p. A - 57)
Vary Powder Amounts (p. A - 58)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
10 minutes	10 minutes	20 minutes	10 minutes

SUPPLIES

Item	Amount Needed
sealing plastic bags (e.g., Ziploc™)	2 per group
plastic cups, 8 oz.	2 per group
permanent markers (e.g., Sharpie™)	1 per group
plastic spoons (e.g., teaspoon size)	2 per group
pop-top squeeze bottles (e.g., water or sports drink) 6 oz. or larger	1 per group
Epsom salts	¼ cup per group
laundry detergent (must contain sodium carbonate—available in grocery stores)	¼ cup per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Laundry Detergent:

- The detergent must contain sodium carbonate (also called washing soda), so not all brands will work. Check the label. Try out these detergents first: Arm & Hammer Fabricare™, BioKleen™, Seventh Generation™.

Cups:

- Label the two plastic cups for each group "D" and "E" for "Laundry Detergent" and "Epsom Salts."
- Fill each cup with ¼ cup laundry detergent or Epsom salts.

Water Bottles:

- Fill pop-top squeeze bottles with room temperature water.

Notes and Hints

- Room temperature water is best for this experiment since it will allow the greatest range of temperature changes to be observed.

SETUP

For each group
- ❑ 2 sealing, plastic sandwich bags
- ❑ permanent marker
- ❑ plastic cup labeled "E" with ¼ cup Epsom salts
- ❑ plastic cup labeled "D" with ¼ cup laundry detergent
- ❑ 1 plastic spoon
- ❑ water in a pop-top squeeze bottle

In a central location (or with the teacher)
- ❑ sponges and towels for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

In this reaction, students observe chemicals release or absorb heat when they dissolve in water.

What things in the world give off heat?
Possible answers are stoves, light bulbs, car engines, fires, people, the sun, pavement on a hot day, volcanos, friction (e.g., from rubbing hands together).

What causes the heat in these things?
Stoves and light bulbs use electricity to heat metal. In fires, a chemical reaction between the wood and air releases heat. People stay warm by the chemical reactions between their bodies and the food they eat. The sun is hot because of nuclear explosions that release heat. Finally, friction from rubbing hands releases heat by a simple mechanical process of rubbing molecules together.

For 5th–8th grades
Heat is a type of energy. Things that have this energy are hot, while those without much heat energy are cold. What things in the world do not have that much heat in them?
Possible answers are ice, fridges, snow, winters, mountain tops, Antarctica, etc. A follow up question might be: "Where did their heat go?"

Hot and Cold Packs
This demonstration is best performed AFTER the students have completed their experiments.

Supplies

- Hot packs: Chemical hand warmers containing sodium acetate can be found at camping/outdoor stores. Other hand warmers may use iron filings. Follow the directions on the package for activation.
- Cold packs: These can be found at sporting good stores, drug stores, or other places where first aid items are sold. Most of these contain urea and water as the active ingredients.

Demonstration

- Pass around a hand warmer and cold pack before activation. Allow students to feel the beginning temperature.
- Activate the hand warmer and cold pack. Pass these around again so students can compare.

Explanation

Many hand warmers contain sodium acetate dissolved in water. Upon activation, the sodium acetate solidifies, releasing energy (an **exothermic** process). Others contain powdered iron that reacts with water and the oxygen in the air (that is, it rusts) to release heat.

Most cold packs contain solid urea and a small packet of water. Crushing the water packet allows the urea to dissolve in the water. This process absorbs energy so the pack feels cold (an **endothermic** process).

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page A - 61, working in groups of 2–4. Below are suggestions to help the teacher facilitate the activity.

NOTES

Matter of Degree

This handout is on p. A - 61.

SCIENTIFIC PROCEDURE

1. Label one plastic bag "D" for laundry detergent. Label the other bag "E" for Epsom salts.

2. Add three spoonfuls of water to each bag.
- Feel the bag. What does it feel like?

3. Add one spoonful of laundry detergent to the bag labeled "D", and gently mix the ingredients by squeezing the bag for thirty seconds.

Running Suggestions

- Students can use any size spoon to add the powders to the water in the bags. The exact amount is unimportant.
- Allow the water to come to room temperature before using it in this experiment. If the water is too cold or too hot, the temperature changes produced in this activity will be less noticeable.
- Only detergents that contain washing soda (sodium carbonate) will heat up when they dissolve in water. However, even if washing soda is on the list of ingredients, it's a good idea to try the detergent beforehand (to see how much it will warm up).

Ongoing Assessment

- Why are we squishing the bags? *(To help the powder dissolve.)*
- Which chemical is producing the temperature change—the solid or the water? How do you know? *(It's the interaction of both water and powder that produces the heat change.)*
- Which chemical changes more when they are combined? *(The powder—it changes state, changes color; the water also rearranges to accommodate the powder, but it mostly stays the same color and the same state [liquid].)*

Safety and Disposal Information

- Used bags with their solutions may be thrown in the trash.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What happened to the powders when you added them to water? What happened to the water?
The two powders dissolved in the water. The water that was dissolving detergent warmed up, while the water dissolving Epsom salts got cold.

What would happen if you did this same experiment again with a different amount of water? Would the temperature change? What about a different amount of powder?
Increasing the water reduces the temperature change. The same amount of heat is released or absorbed, but there is more water to heat or cool. Differing amounts of powder also affect the temperature change for similar reasons.

Which powder released energy in the water? Which one abosorbed energy?
The detergent (the warm solution) released energy into our hands, which we felt as heat. The Epsom salts (the cold solution) absorbed energy from our hands. We feel the loss of energy from our hands as "cold."

Do you have to add energy to dissolve detergent in water? What about Epsom salts?
Detergents become warm when they dissolve in water, so they must release some excess energy. This energy warms up the water. Epsom salts need energy to dissolve. They take it from the room temperature water (which has lots of heat compared to, say, water at the North Pole), making the water colder.

How might heating or cooling reactions help us in everyday life?
First aid cold packs or heat packs, de-icers for roads or airplane wings, etc. Also, many of the chemical reactions in our bodies (such as digesting food) produce heat—this keeps us warm and helps our brains and bodies work. When we exercise, the increased chemical reactions in our muscles heat us up more.

What other chemical reactions produce heat? Can you think of any reactions that absorb heat?
When wood, paper, or gasoline burn, those chemical reactions produce heat. The heat from burning gasoline helps to move the pistons in a car engine, making the wheels turn. Reactions that absorb heat are more rare, but dissolving baking soda in water is an everyday example (see Extension A).

EXPLANATION

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

When chemicals combine in new arrangements, they often exchange energy. In this experiment, students discover how dissolving solids in water releases or absorbs energy.

BACKGROUND FOR ALL GRADES

Dissolving powders and temperature changes
When students add detergent and Epsom salts to water, the powders break apart and spread out in the water (i.e., they **dissolve** in the water). This causes the solution temperature to change.

When it dissolves, each powder molecule detaches from other powder molecules and becomes surrounded by water molecules. This change in arrangement either absorbs or releases **energy**. The exchange of energy causes the temperature of the solution to change. When the powder molecules release energy in the solution, it heats up. When powder molecules absorb energy from the solution, it cools down. Students detect the change of energy as a change in temperature.

Misconception Alert: Note that this change in energy happens whenever any solid dissolves in water, even table salt. Detergent and Epsom salt are used in this experiment because they produce noticeable changes in temperature with only small amounts of powder.

Also note that technically, no chemical reaction is occurring (i.e., the powders don't change into something new, and neither does the water). Instead, the molecules are just arranged in a different way, and, in moving to their new arrangement, they either release or absorb energy.

EXTRA BACKGROUND FOR GRADES 6–8

Temperature is Motion

What does it mean to be "hot" or "cold"? If students could look at the "cold" Epsom salt molecules in solution and the "hot" detergent molecules in solution, they would notice something right away. The "hot" detergent and water molecules would all be moving, spinning, and shaking much faster than the "cold" molecules in the Epsom salt solution. 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 (including vibration) 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.

Exothermic and Endothermic Processes

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 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 bag 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.

Misconception Alert: It's important to note that cold is simply the relative absence of heat. We detect "cold" when we touch something cold because the colder object transfers heat out of our hands.

EXTENSIONS

Extension A: Test Other Powders
Other chemicals also release or absorb energy when dissolved in water.

Extra Supplies

- plastic cups (3 per group)
- resealing plastic bags (3 per group)
- plaster of Paris (¼ cup per group)
- baking soda (¼ cup per group)
- calcium chloride (¼ cup per group)
  NOTE: Calcium chloride ($CaCl_2$) is available as a de-icer (brands ComboTherm and Road Runner) or as a dehumidifier (brands Damp Rid or Dry Z Air). Other brands may work too, look on the side panel, and test other brands before using in class.

Extra Instructions

- Label and fill extra plastic cups with plaster of Paris, baking soda, and calcium chloride. Cover until ready for use.
- Follow the Scientific Procedure on p. 10, using these materials instead of Epsom salts and laundry detergent
- NOTE: plaster of Paris takes 10–12 minutes to react and become warm.

Explanation

The calcium chloride and the plaster of Paris both get warm when dissolved in water. Baking soda gets cold.

CAUTION: Calcium chloride can get VERY hot when dissolved in water (150–190°F). This may be too hot to comfortably handle.

Extension B: Measuring Temperature Change

Students measure the temperature change of the solutions using thermometers and Styrofoam cups. Older students can graph the results of a time series of measurements.

Extra Supplies

- thermometers (1 per group)
- Styrofoam cups (2 per group)

Extra Instructions

- Students can practice designing an investigation and measuring and graphing (older students) their results by using thermometers and Styrofoam cups.

- If possible, facilitate a student discussion of when to measure the temperature change, how to display results (bar graph? table?), how much water to use, how to use the thermometer, etc.
- Remind students to record the temperature of the water before adding any chemicals. Have students graph their results.

Extension C: Vary Amounts of Powder

Students compare temperature change with differing amounts of solid using thermometers and Styrofoam cups. They can then measure the temperature change as in Extension B, and older students can graph those changes.

Extra Supplies

- thermometers (1 per group)
- Styrofoam cups (8–12 per group, depending on how many amounts are investigated)
- one ⅛, ¼, or ½ teaspoon measure (to produce a number of different solid amounts) (Note that with a single ⅛ teaspoon, students can measure ⅛, ¼, ⅜, ½, ⅝, etc., teaspoons of the powders.)

Extra Instructions

- This extension is very similar to Extension B above, except that students vary the amount of solids that dissolve in the same amount of water.
- Discuss how to set the experiment up with the students, being sure to ask older students how to collect their results (i.e., in a graph, on a chart?) since there will be many different results from this investigation.
- Students should prepare data collection sheets and label their cups.
- **Note:** It is important that students measure the starting temperature of the water before they add any powder. For instance if students use the ⅛ teaspoon six times to measure ¾ teaspoon of solid, the solution temperature changes with each addition. So the starting temperature is BEFORE they added the first ⅛ teaspoon of powder.
- If students find they can't change the temperature any more, ask them to hypothesize why.

Explanation

The more powder that dissolves, the more the temperature will change, up to a point. When the water can't dissolve any more powder, adding more powder won't really affect the temperature. It is the process of dissolving that changes the temperature. Note that the solubility of the powder in the water is affected by temperature. As the water warms up, it can hold more detergent. Conversely, when it cools down, the water can dissolve less Epsom salt. This effect complicates the results of the experiment but can provide an interesting discussion that may lead to further experimentation.

CROSS-CURRICULAR CONNECTIONS

BIOLOGY **Hypo- and Hyperthermia**
Have students research hypo- and hyperthermia.

MATHEMATICS **Graphing Temperature Change**
Complete Extension B or Extension C. Graph results.

LANGUAGE ARTS **Extreme Environments**
Have students read books set in extreme temperature environments. These may be novels or factual accounts of survival in these areas. Extremely cold environments: Antarctica, Iceland, Greenland, the Arctic, Mars. Extremely hot environments: Tunisia, Coober Pedy, Australia, the Sahara Desert, Venus.

RESOURCES

Lerangis, Peter, *Antarctica: Journey to the Pole*
Reading Level: 3rd to 8th grade
An exciting novel packed with thoroughly researched information. Each chapter told from a different crew member's point of view.

Raskin, Lawrie, *52 Days by Camel: My Sahara Adventure*
Reading Level: 4th to 8th grade
Photographer Lawrie Raskin traveled to Timbuktu from Fez on a series of excursions riding buses, jeeps, trucks, a train, and a camel. Lively narrative. There are maps for each leg of the journey that are color coded with dots that match accompanying text. Also includes cultural information about survival in this extreme environment. Clear, bright, full-color photos abound.

Ryan, Zoe Alderfer, *Ann and Liv Cross Antarctica: Dream Come True*
Reading Level: 3rd to 8th grade
A factual account of the Bancroft Arnesen Expedition across Antarctica aimed at ages 9–12.

Forgey, William, *Basic Essentials: Hypothermia*
Reading Level: 4th to 8th grade
An information-packed tool for the novice or handy reference for the veteran. Distills years of knowledge in an affordable and portable book.

VOCABULARY

dissolve: when the molecules of a substance separate and become completely surrounded by the molecules of another substance

endothermic: a process that absorbs energy, causing it to feel cool; *endo* means *into*

energy: the ability to do work; anything that is not matter

exothermic: a process that releases energy, causing it to feel warm; *exo* means *out of*.

temperature: a measure of the energy of a substance, based on how fast its molecules are moving

Matter of Degree

SCIENTIFIC PROCEDURE

1. Label one plastic bag "D" for laundry detergent.
Label the other bag "E" for Epsom salts.

2. Add three spoonfuls of water to each bag.
- Feel the bags. What do they feel like?

3. Add one spoonful of laundry detergent to the bag labeled "D". Seal the bag and gently mix the ingredients by squeezing the bag for 30 seconds.
- What does the bag feel like now?

4. Add one spoonful of Epsom salts to the bag labeled "E". Seal the bag and gently mix the ingredients by squeezing the bag for 30 seconds.
- What does the bag feel like now?

5. Compare the two bags.
- How are the contents of the two bags the same?
- How are the contents of the two bags different?

6. Clean up your area.
- Follow your teacher's instructions.

This worksheet is available online at **www.omsi.edu/k8chemistry.**

A Matter of Degree

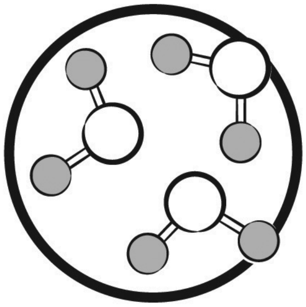
Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
sealing plastic bags (e.g., Ziploc™)	2 per group		
small plastic cups	2 per group		
permanent markers (e.g. Sharpie™)	1 per group		
spoon (e.g., teaspoon size)	2 per group		
pop-top squeeze bottles (e.g., water or sports drink) 6 oz. or larger	1 per group		
Epsom salts	¼ cup per group		
laundry detergent (must contain sodium carbonate—available in grocery stores)	¼ cup per group		
Extension A			
plastic cups	3 per group		
sealing plastic bags	3 per group		
plaster of Paris	¼ cup per group		
baking soda	¼ cup per group		
calcium chloride	¼ cup per group		
Extension B			
Styrofoam cups	2 per group		
thermometers	1 per group		
Extension C			
thermometers	1 per group		
Styrofoam cups	8–12 per group depending on how many amounts are investigated		
⅛ teaspoon measure	1 per group		
¼ teaspoon measure	1 per group		
½ teaspoon measure	1 per group		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Teacher Demonstration			
Hot and Cold Packs			
Hot packs: Chemical hand warmers containing sodium acetate can be found at camping/outdoor stores. Other hand warmers may use iron filings. Follow the directions on the package for activation.	1–2 per class		
Cold packs: These can be found at sporting good stores, drug stores, or other places where first aid items are sold. Most of these contain urea and water as the active ingredients.	1–2 per class		



Salting Out

Learning Objectives: *Students learn general rules of why some substances will mix and some won't.*

GRADE LEVEL

6–8

SCIENCE TOPICS

Physical Properties
Atoms and Molecules
Solutions and Mixtures

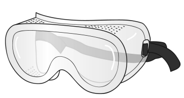
PROCESS SKILLS

Describing/Defining
Predicting
Explaining

GROUP SIZE

2–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students separate a solution into colored layers.

STUDENT SUPPLIES

see next page for more supplies

isopropyl alcohol
old permanent markers (e.g., Sharpie™)
salt
small glass jars with lids (e.g., baby food jars)

ADVANCE PREPARATION

see next page for more details

Label pop-top squeeze bottles, etc.

OPTIONAL EXTRAS

DEMONSTRATION

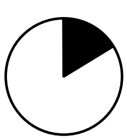
Oil and Water (p. A - 69)
Oil and Water and Soap (p. A - 70)

EXTENSIONS

Candy Color (p. A - 77)
Inquiry Opportunity—Test Solubility (p. A - 78)
Measure Layers (p. A - 78)

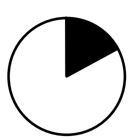
TIME REQUIRED

Advance Preparation



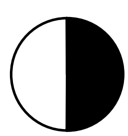
10 minutes

Set Up



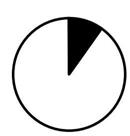
10 minutes

Activity



30 minutes in each of two class sessions

Clean Up



5 minutes

SUPPLIES

Activity Note:

To increase student comprehension, run this activity over two class sessions. In the first, perform the two Teacher Demonstrations: *Oil and Water* and *Oil, Water, and Soap*. Discuss polarity with older students. Then take the second session to run the experiment in the jars.

Item	Amount Needed
small jars with lids (e.g., baby food jars)	4 per group
masking tape	1 roll per group
permanent markers (e.g., Sharpie™)	1 per group
pop-top squeeze bottles (e.g., water or sports drink)	2 per group
isopropyl alcohol (at least 90% concentration)	½ cup per group
water	½ cup per group
salt	½ cup per group
plastic cups, 8 oz.	1 per group
teaspoon measures	2 per group
8½" x 11" plastic protective sleeves (optional)	1 per group

For Extension and Demonstration supplies, see the appropriate sections.

ADVANCE PREPARATION

Supplies Preparation

Markers:
- Use OLD (relatively dry) permanent markers. New markers are so full of alcohol and ink that they will leak into water solutions. Old markers will still nicely color alcohol solutions.

Salt:
- Fill cups with about ½ cup of salt.
- Label the cups "salt."

Water:
- Fill pop-top squeeze bottles with about ½ cup of water.
- Label the bottles "water."

Alcohol:

- Use at least 90% concentration of isopropyl alcohol; 99% is best.
- Fill pop-top squeeze bottle with about ½ cup of alcohol.
- Label pop-top squeeze bottles "alcohol, 90%" or with what percent you use.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

Notes and Hints

- To protect Instruction Charts from spilled liquids, insert each page into a plastic protective sleeve or laminate (optional).

SETUP

For each group

- 4 small glass jars with lids
- roll of masking tape
- permanent marker
- pop-top squeeze bottle of alcohol
- pop-top squeeze bottle of water
- salt in plastic cup
- 2 teaspoons
- Instruction Chart (suggestion: in protective sheet or laminated)

At a central location (or with the teacher)

- sponges and towels for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will color an alcohol solution using a permanent marker. Then they will mix the solution with water and see a big colored solution. Finally, they will add salt, shake, and observe the solution separate into a colored alcohol layer and a clear water layer.

Let's list a few things that can dissolve in water.
Salt, sugar, honey, baking soda, baking powder, almost all acids and bases, lye, lemon juice, carbon dioxide (e.g., in soda), oxygen gas (e.g., in streams where fish breathe it), bath salts, food coloring.

What does it mean to dissolve? When you add something to water, how do you know it has dissolved?
When a substance is added to water, if it dissolves, the molecules move apart from each other and become completey surrounded by water molecules. One way to tell that something has dissolved is that the water looks clear. It may still have a color, but you can see through it.

Water is a great solvent, meaning it can dissolve many different things. Some scientists even call water a "universal solvent" because it dissolves so much. But does that mean it will dissolve everything? Can you give me some examples of substances that don't dissolve in water?
Sand, plastic, metal, oil, gasoline, kerosene, pennies, butter, people, glass, wood, permanent ink.

Is it possible to change water so that it dissolves things faster, or so that it dissolves more substances?
Yes, you can raise the temperature to dissolve more solids (e.g., sugar), or you can increase the pressure to dissolve more gases (e.g., the pressurized water in closed soda cans holds more bubbles).

Is it possible to change water so that substances will not dissolve?
Yes. Cooling water makes it less able to dissolve things, which is why hot chocolate mix powder collects on the bottom of mugs as the hot chocolate cools. In soda cans, shaking up the soda can cause the gas to escape. Finally, if the amount of water is reduced (through evaporation or boiling, for instance),any dissolved solid may come out. An example is ocean water leaving a salt crust as it dries on skin.

Oil and Water

This demonstration is best done before the activity. This will show students two liquids that don't mix, as well as a colored molecule that only dissolves in water

Supplies

- clear plastic bottle with lid (20 oz., 1-liter, etc.) or clear jar with lid
- water
- food coloring
- vegetable oil

Procedure

- Fill the plastic bottle halfway with water. Show this to the students.
- Add a few drops of food coloring. Mix and show this to the students. Does the food coloring dissolve in the water? How do you know?
- Add enough vegetable oil to the water to create a layer at least ½–1 inch thick. Screw the top on the bottle and shake it to mix the contents.
- Show the bottle to the students. Did the oil and water mix? How do you know? Where is the oil? Where is the water? Where is the food coloring?

Explanation

Oil and water are made of different types of molecules. The molecules in water have a small positive and a small negative charge, a bit like the poles on a magnet. We call such molecules with partial charges **polar molecules**. The molecules in oil have almost no positive or negative charge. We call these molecules **non-polar molecules.**

Different kinds of molecules do not mix well with each other. Polar molecules like to associate with other polar molecules. The molecules in the food coloring are polar (that is, they also have charges on them), so they mix with the water and not with the oil.

NOTE: The oil floats on the water because it is less dense than water. For a more detailed discussion of density, see the Explanation section of ***Density Rainbow***.

Oil and Water and Soap
Continue from the previous demonstration to make oil and water mix. Soap will help the two liquids dissolve in each other.

Supplies
- bottle from last demonstration filled with oil and colored water
- liquid soap (hand soap, dish soap)

Procedure
- Add a squirt or two of soap to the mixture from the last demonstration. At first, the soap will likely sit between the water and oil layers, but then will sink to the bottom.
- Screw the top on the bottle and shake it to mix the contents.
- Show the bottle to the students. Did the oil and water mix? How do you know? Where is the oil? Where is the water? Where is the food coloring? Where is the soap?

Explanation

Soap molecules are long chains. On one end, there is a charge, meaning that this end of the soap molecule can mix with water. The rest of the molecule has no charge, meaning it can mix with oil. Soap therefore acts like a bridge between oil and water molecules to help them all mix together. After shaking the mixture and letting it sit for a while, the layers may separate again, but students should notice that the layers are not distinct. The food coloring seems to be in both layers, and it is hard to tell where the oil is and where the water is.

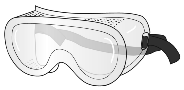
> **Note:** For a more detailed description of how oil and water can be mixed together with soap, see the Explanation section for **DNA Extraction**. The second part, for older students, shows oil dissolving with soap in water.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page A - 82, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.

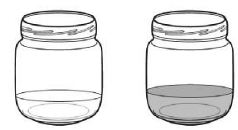


Salting Out

SCIENTIFIC PROCEDURE

This handout is on p. A - 82.

1. Label two spoons with masking tape one for "liquid" and one for "salt." Also label four jars with the numbers 1-4 . Set the jars up on the Instruction Chart.
2. Look at the Instruction Chart and then add water or alcohol to the jars according to its directions.
3. In the next step you will add salt to Jar 1 and Jar 2. But before you do so:
   - **Predict:** Do you think the salt will dissolve in the water?
   - **Predict:** Do you think the salt will dissolve in the alcohol?



4. Now, add 1 spoonful of salt each to Jar 1 and to Jar 2. Put the lids on each jar and shake vigorously for 20–30 seconds.
   - **Record:** Describe what the salt and water look like

Running Suggestions

- To increase student comprehension, run this activity over two class sessions. In the first, perform the two Teacher Demonstrations: Oil and Water and Oil, Water, and Soap. Discuss polarity with older students. Then take the second session to run the experiment in the jars.
- Make certain students tightly close the jars before shaking them.
- Students should record their observations as the procedure sheet prompts them. Encourage students to use detail. If a question comes before a step, the student should record their answer to the question BEFORE doing that step.

You may want to instruct students to write their answers and draw pictures on separate pieces of paper so they will have more space to write.

- Old permanent markers work better because they produce better color separations than new ones. Brand new permanent markers may even color both the water and the alcohol. (New markers are so full of alcohol and ink that both can leak into the water.)

Ongoing Assessment

- What can happen when you combine two substances? *They can mix, they can stay separate, or they can react to make something new.*
- How do you know if something has dissolved? *It so finely disperses as to become invisible in the liquid. The liquid is clear, you can see through it, but it may have a color. At this point, each molecule of salt is completely surrounded by liquid molecules.*
- Why do you think some chemicals dissolve and some don't? *They have different chemical properties; in this case, things dissolve if they have similar charges. The charges on the water are attracted to the charges on the alcohol.*
- Can you explain why the alcohol and water separate when you add salt? *The salt strongly attracts the water and the salty water has too much charge to dissolve the alcohol.*

Figure 1. After adding salt, the alcohol and water should separate into two layers. The marker ink stays with the alcohol layer that is on top. The salt stays with the water layer that is on the bottom.

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Waste isopropyl alcohol should be kept away from all sparks and flames. The small amounts used in this experiment may be poured down the sink drain with lots of water.
- All other materials can be thrown away as solid waste.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Did the salt dissolve in the alcohol? Did the salt dissolve in the water?
Answers will vary. Some salt actually does dissolve in the alcohol but not very much. The alcohol is less polar than the water, so its charges are less well attracted to the charged particles in salt. Much more salt dissolves in the water, but the water can only hold so much salt.

Permanent markers are designed to not dissolve in water. Did the ink dissolve in the water? Did it dissolve in the alcohol? Why does it dissolve in the water and alcohol solution?
The permanent ink is more like the alcohol than the water. However, because the alcohol can dissolve with the water, the alcohol carries the marker ink into the water when it dissolves in the water. The alcohol acts as a bridge in the solution to keep the marker ink dissolved.

When you added the salt to the colored water and alcohol, what happened to the salt? Did it dissolve in the water or the alcohol?
Answers will vary. The salt dissolved mostly in the water, but some in the alcohol. It's hard to tell where which liquid dissolved the salt just by

looking. One way to find out is to take one drop of each liquid and let it evaporate, to see which leaves behind more salt.

At the end of the experiment, which layer was alcohol and which was water? How do you know? Why do you say so?
The marker ink helps us guess the alcohol layer is on top. Another way to figure out which layer is which is to add a bit more water. If the water passes through the top layer and collects on the bottom, the top layer is alcohol. If the water stays on the top and increases the width of the top, the top layer is water.

The alcohol layer seems to be smaller than the water layer, but we started out with more alcohol, right? Why do you think it is smaller?
Answers will vary. The layer on top is small because some of the alcohol is dissolved in the lower water layer, even though the water is salty. In actual fact, neither the alcohol nor the water layers are completely pure—some alcohol remains dissolved in the water layer, and vice versa. NOTE: Observant students might point out that the water layer must have dissolved more of the alcohol, since the alcohol layer is smaller.

To further investigate this last question, students can complete Extension B.

EXPLANATION

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

In this activity, students make a colored solution of permanent marker ink, water, and alcohol. Then they cause the solution to form separate, colored layers by adding salt.

Like Dissolves Like—Salt in water
Salt dissolves in water because it is "like" water in a chemical way. Students explore this idea in the activity when they add salt to both water and alcohol. The salt **dissolves** easily in the water but does not dissolve very well in the alcohol. This demonstrates a common phenomenon in chemistry, that **"like dissolves like,"** or that chemicals that have similar properties will dissolve in each other. Thus, we see that salt and water have "something" more in common than salt and alcohol. Another place to see this is in the Teacher Demonstration, Oil and Water. Oil and water do not mix at all; they are **insoluble**. This implies that water and oil have very different chemical properties.

Like Dissolves Like—Permanent marker ink in alcohol
Permanent marker dissolves in alcohol because it is "like" alcohol in a chemical way. It does not dissolve in water because it is chemically unlike water. Students explore this idea when they add permanent marker to both the water and alcohol. *

After the solutions separate, students notice that the color from the permanent marker stays in the alcohol layer, not the water layer. Permanent marker ink is designed to resist washing with water (i.e., water does not dissolve it), but the ink dissolves easily in alcohol. Permanent marker ink must share some chemical properties with alcohol and not with water.

Alcohol and Water
Even though alcohol and water act differently when compared with salt or with marker inks, they are similar enough to dissolve in each other quite well. Students investigate this when they mix their colored alcohol and water: they find the color is evenly distributed through the entire mixture. This shows that the alcohol and water are **soluble** (will dissolve in each other). It also shows that permanent marker ink will dissolve in water when alcohol is present.

Students might construct a continuum like the following:

Salt.......................Water .... Alcohol..........................Permanent Marker Ink

Chemicals near each other on this chart are similar and will dissolve together, but chemicals that are far apart will not.

Salting Out—Separating alcohol and water
Adding salt to water/alcohol mixtures can separate them into layers. Even though water and alcohol mix well together, alcohol and salt do not. When salt is added to the solution, the salt dissolves in the water but not in the alcohol. Two layers are formed, with the alcohol layer on top. The marker ink allows us to see the separation more clearly, as it travels with the alcohol layer.

NOTE: The alcohol layer floats on the saltwater layer because it is less dense than water or saltwater. For a more detailed discussion of density, see the Explanation section of **Density Rainbow**.

* **Note:** Students might find that brand new permanent marker ink seems to dissolve in water. However, this isn't really the case. Marker ink contains some alcohol, and a new marker has enough alcohol that some of the alcohol leaks into the water, carrying some of the dissolved ink. This allows the ink to mix in the water to a certain extent.

EXTRA INFORMATION

Charges on Molecules

When chemists say that "Like Dissolves Like," they really mean "like charges dissolve like charges." In other words, to understand whether solids or liquids dissolve together (i.e., are **soluble**), it is necessary to look at the electrical charges on the molecules. These charges come from how the **electrons** (negatively charged particles) are shared between atoms.

When atoms combine to make molecules, they can share their electrons in one of three ways: the atoms can share the electrons equally, one atom can take the electrons completely, or they can share the electrons unequally. The way the electrons are shared determines the overall charge of the molecule (see Figure 2).

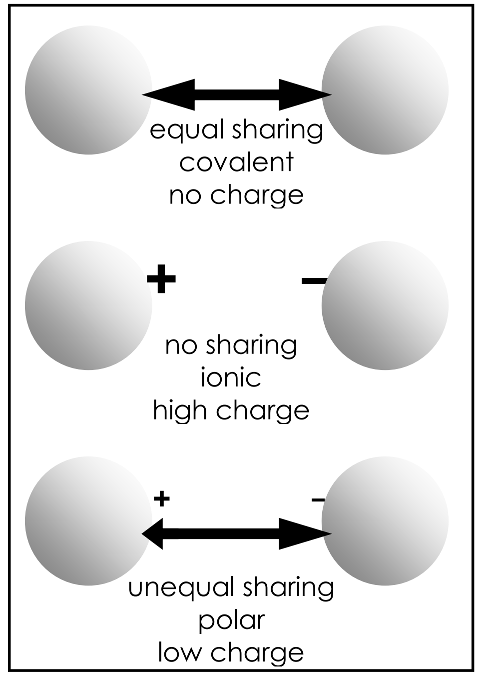


Figure 2. How atoms can share electrons.

Equal Sharing = Covalent

An example of almost equal sharing is found in oil. Molecules of vegetable oil have very little overall charge because most the atoms share the electrons almost equally. In mineral oil the sharing is even more equal, and the overall charge is even smaller. This type of sharing between atoms results in **covalent** chemical bonds.

No sharing = Ionic

An example of no sharing of electrons is found in table salt, where one atom (chlorine) completely takes the electron and acquires a strong negative charge. The atom that donated the electron (sodium) ends up with a strong positive charge. These opposite charges attract to form an **ionic bond**.

Misconception Alert: Even though the parts of the molecule have positive and negative charges, they cancel out, so each molecule has a total net charge of zero.

Unequal Sharing = Polar

Examples of unequal sharing are found in water and alcohol, where the atoms share the electrons unequally. Because the electrons are held nearer to one of the atoms, it acquires a partial negative charge, while the other atom gets a partial positive charge

Because the atoms partially share the electrons, this type of bond is considered a covalent bond; however, it is called a **polar** bond because it is partially charged.

It is important to note that water shares its electrons much more unevenly than alcohol, so its molecules are much more charged (but still not completely charged like the salt).

Misconception Alert: Even though the parts of the molecule have small positive and negative charges, they cancel out so each molecule has a total net charge of zero.

Charge and Solubility

The charges on the molecules in chemicals like water, oil, alcohol, and salt affect how much they dissolve in each other. Salt molecules are very charged, so they dissolve easily in water, which has slightly charged molecules. Salt dissolves less easily in alcohol, because alcohol molecules have less charge than water.

Alcohol also has a portion of its molecule that has no charges, i.e., it is **non-polar**, like oil. This portion is less compatible with water and more compatible with non-polar molecules. Under normal circumstances, alcohol can dissolve in both polar and non-polar substances. This implies that permanent marker ink has molecules that have little or no charge since they dissolve in alcohol but not in water. Because alcohol dissolves with both water and permanent marker ink, the alcohol acts as a bridge between the water and the permanent marker ink allowing all three to mix together.

Finally, salt doesn't dissolve in oil at all because oil has practically no charge at all. Some of these relationships are shown in Figure 3.

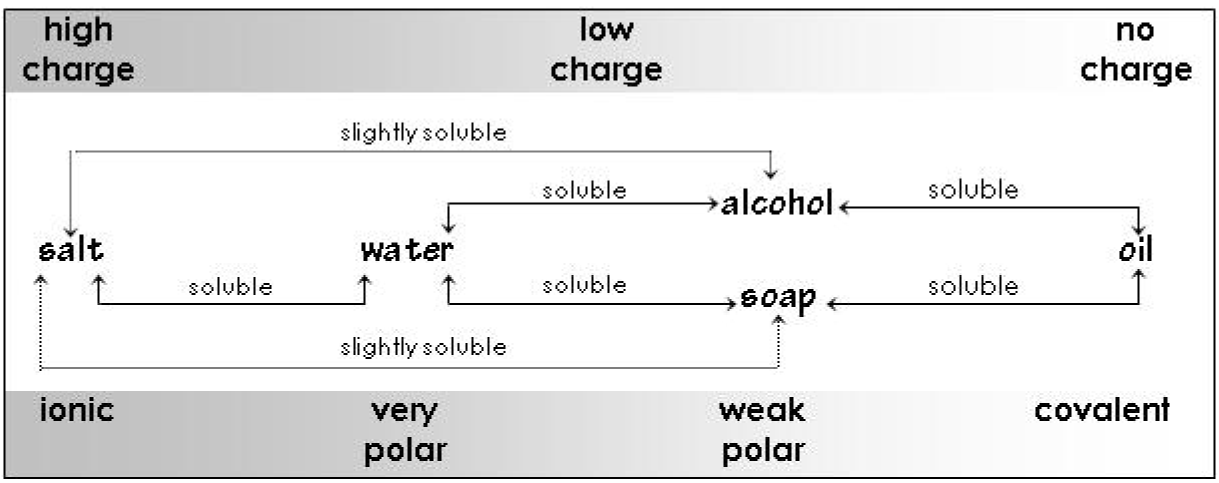


Figure 3. Charge differences explain solubility.

A difference in charge also explains why oil and water will not mix. Since oil molecules are almost entirely uncharged, they won't mix with charged water molecules. Wax, fat, and rubber are also made of uncharged molecules and are similarly "waterproof."

Some chemicals can dissolve in two different chemicals that don't dissolve in each other. For example, soap and alcohol can dissolve in both water and oil, even though water and oil don't mix. What's more, when soap (for instance) mixes with oil and water together, it helps the oil and water mix. (This is how soap and water remove cooking oil from pans.) In this way, soap acts as an **emulsifier** since it is helping two liquids mix that normally won't.

Salting Out Revisited
When students add salt to the mixture of water, alcohol, and permanent marker ink, the mixture separates into two separate layers. One layer has alcohol and permanent marker ink, and one layer has salt and water. With its high charges, the salt dissolves much more easily in the water. This makes the saltwater mixture too charged for the alcohol to stay in solution. The salt effectively repels the alcohol, and the mixture separates.

Salting Out Applications
Chemists use salt to alter the charge of water solutions when they want to precipitate proteins, separate polar liquids from water, or concentrate dissolved chemicals (like the marker ink) in a non-water layer.

Scientists take advantage of how salt dissolves in water to purify proteins. When **biochemists** study the chemistry of the body, they often focus on the proteins, because understanding how proteins work can help them design new medicines, diagnose diseases, and understand how genes work. Unfortunately, though, most of the interesting **proteins** and other biological molecules of the body are dissolved in the watery interior of the cell. It can be very difficult to separate one protein from the thousands of other proteins and molecules.

One way to isolate proteins for study is to add precise amounts of salt to "salt out" the proteins. This forces the proteins to **precipitate**, or leave the water solution, similar to the way the colored alcohol does in the students' experiment. Adding salt increases the charge of the overall solution, and, because all proteins have different charges, they precipitate from the salt water solution at different concentrations of salt.

EXTENSIONS

Extension A: Candy Color
The dyes in many candies will dissolve in the water layer, not the alcohol. Students can use these candies to color the water layer in the jars. If the students want to color both the layers at the same time (that is, use candies to color the water and markers to color the alcohol), they should avoid using candies that are the same color as the marker.

Extra Supplies
- water soluble dyes: M&M's™ candies, Skittles™ candies

Extra Instructions
- Follow the same procedure as the general activity.
- Substitute (or add) candies in Step #7 for the permanent marker.

- Students should use two candies for each jar and leave them in the solution briefly. They should remove the candies before the colored coating dissolves completely (because, for example, the chocolate in M&M's™ will dissolve and make a murky solution).

Extension B: Inquiry Opportunity—Test Solubility
Ask students what other compounds they think will dissolve in only water or in only alcohol. Why or why not? For example, "waterproof" or "water resistant" compounds (such as permanent markers) are more likely to dissolve in only alcohol. Other compounds are more likely to dissolve in water.

Extra Supplies
- dyes of unknown solubility: dry erase markers, overhead pens, colored markers, squares of paper with color printed from a computer, candies (as in Extension A above)

Extra Instructions
Students can repeat the entire procedure, but use another dye in place of marker inks. When students complete the procedure, they can evaluate whether their dye was successfully separated into either the alcohol or water layer.

Extension C: Measure Layers
After the salting out procedure is finished, students should add more of one ingredient to the layered solution. What will happen? Will both layers get bigger? Will one layer grow and the other shrink? By measuring the width of each layer beforehand, students can see the difference and calculate ratios.

Extra Supplies
- ruler (1 per group)
- extra alcohol
- extra water
- extra salt

Extra Instructions
1. Add alcohol
    - After completing the original Scientific Procedure, students should measure the depth of each layer in the jar.
    - Add one teaspoon of alcohol to the layers in Jar 3. Recap the jar and shake for 20–30 seconds
    - Re-measure the layers.
    - Students can repeat adding alcohol and re-measuring until the jar is full.

2. Add water

- Start over. Recreate the layers in Jar 3 by redoing the original Scientific Procedure (students can skip any reference to Jar 1 and Jar 2).
- Measure the depth of each layer in Jar 3.
- Add one teaspoon of water. Recap Jar 3 and shake for 20–30 seconds.
- Re-measure the layers.
- Students can repeat adding water and re-measuring until Jar 3 is full.

3. Add salt

- Start over again! Recreate the layers in Jar 3 by redoing the original Scientific Procedure (students can skip any reference to Jar 1 and Jar 2).
- Add one teaspoon of salt. Recap Jar 3 and shake for 20–30 seconds.
- Re-measure the layers.
- Students can repeat adding salt and re-measuring until no more salt will go into solution.

Explanation

- When alcohol is added: The alcohol layer increases in depth while the water layer decreases. This happens because the larger amount of alcohol is able to absorb (i.e., dissolve) some of the water. The water layer will shrink as the alcohol layer grows. Eventually the layers combine into one mixture of alcohol, water, and salt.

- When water is added: This is more or less the opposite of adding alcohol. The water layer increases in depth and the alcohol layer decreases—the increased amount of water can dissolve more of the original alcohol. The alcohol layer will shrink as the water layer grows. Eventually the layers combine into one mixture of alcohol, water, and salt.

- When salt is added: the salt dissolves mostly in the water, changing the water and making it less able to mix with the alcohol. This causes the alcohol layer to grow. The water layer appears to shrink, but it is hidden inside the growing pile of salt at the bottom of the jar.

CROSS-CURRICULAR CONNECTIONS

BIOLOGY

Cell Biology
Research the parts of the cell, the process of membrane transport, and the contents of the cytoplasm. Find out how the chemicals in the cytoplasm guide the cell in deciding what enters and leaves the cell through the membrane.

SOCIAL STUDIES

The Importance of Salt
The impact of salt on economies, trade, and culture is vast. Research the important role salt has had in food preservation, the growth and strength of cultures, and even in war.

RESOURCES

Web – http://en.wikipedia.org/wiki/Polar_molecule
An introduction to the concept of polar and non-polar molecules, with pictures and diagrams.

Web – http://chem4kids.com
An excellent website with information on all chemical concepts. Their site map has a well-organized topic index. The topics "Solutions," "Mixtures 1," and "Mixtures 2" are relevant to this activity.

Web – http://www.saltinstitute.org/38.html
The Salt Institute has an extensive site explaining the place salt has in history, politics, and economics.

Frankel, Jill and Kline, Michael, *Super Science Concoctions: 50 Mysterious Mixtures for Fabulous Fun*
Reading Level: 3rd to 8th grade
Well-organized, detailed recipes, fun activities, and thorough, accurate scientific explanations. The first section focuses on solutions and mixtures; later sections explore other chemistry topics.

VOCABULARY

biochemists: scientists who study the chemistry of life processes

covalent bonds: connections between atoms where the electrons are equally shared; molecules with these bonds tend to be balanced electrically

dense: describes how tightly packed matter (molecules, people) is in a space; dense is the adjective, density is the noun

dissolve: when the molecules of one substance separate and become completely surrounded by the molecules of another substance

electron: negatively charged particle found in atoms

emulsifier: something added to two liquids that normally won't dissolve to keep them uniformly mixed

like dissolves like: the principle in chemistry where substances with similar molecules mix well

insoluble: unable to dissolve

ionic bonds: connections between atoms where the electrons are transferred from one atom to another; molecules with these bonds tend to be highly charged

non-polar: describes neutral molecules whose charges are electrically balanced

polar bonds: connections between atoms where the electrons are not equally shared; molecules with these bonds tend to have a small, unbalanced electrical charge

polar molecules: molecules with partial electrical charges

precipitate: to come out of a liquid solution as a solid

protein: a large, complex biological molecule found throughout the body; hormones, enzymes, and antibodies are all proteins, as are many of the structural parts of the body

salting out: adding salt to a solution of water and another liquid in order to separate or purify the liquid components

soluble: able to dissolve in a particular substance

Salting Out

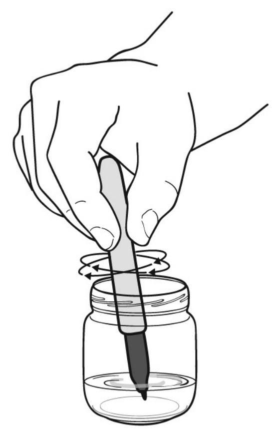
SCIENTIFIC PROCEDURE

1. Label two spoons with masking tape, one for "liquid" and one for "salt." Also label four jars from #1 to #4 . Put the jars on the Instruction Chart.

2. Look at the Instruction Chart and then add water or alcohol to the jars according to its directions.

3. In the next step you will add salt to Jar 1 and Jar 2. But before you do so:
   - **Predict:** Do you think the salt will dissolve in the water?
   - **Predict:** Do you think the salt will dissolve in the alcohol?

4. Now, add 1 spoonful of salt each to Jar 1 and to Jar 2. Put the lids on each jar and shake the jars for 20–30 seconds.
   - **Record:** Describe what the salt and water look like.
   - **Record:** Describe what the salt and alcohol look like.



5. Set Jars 1 and 2 aside.

6. In the next step you will add permanent ink to Jar 3 and Jar 4. But before you do so:
   - **Predict:** Do you think the ink will dissolve in the water?
   - **Predict:** Do you think the ink will dissolve in the alcohol?

7. Now swirl the tip of a permanent marker in the liquid in Jar 3 for 10 seconds. Repeat for Jar 4. Put the cap back on the marker when you're finished. Put the lids on each jar and swirl them for 5 seconds.
   - **Record**: Describe what the ink and water look like.
   - **Record**: Describe what the ink and alcohol look like.

8. In the next step (but not yet), you will mix the contents of Jar 4 with those of Jar 3. Before you do so, what do you think will happen?

- **Predict:** Draw and label a picture of what you think the mixture will look like. Where will the water be? Where will the alcohol be? Where will the ink be?

9. Now, pour the alcohol from Jar 4 into the water in Jar 3. Put the lid on the jar and swirl for 5 seconds to mix.

- **Record:** Draw and label a picture of the mixture. Where is the water? Where is the alcohol? Where is the ink?
- **Record:** Explain how you know where all the ingredients are.

10. In the next step, you are going to add salt to the mixture. Before you do so, what do you think will happen?

- **Think:** Read over your results so far.
- **Predict:** Draw and label a picture of what you think the mixture will look like after the salt is added. Where will the water be? Where will the alcohol be? Where will the ink be? Where will the salt be?

11. Now, Add 1 spoonful of salt to the mixture in Jar 3. Put the lid on the jar, and shake it for 20–30 seconds.

- **Record:** Draw and label a picture of your mixture. Where is the water? Where is the alcohol? Where is the ink? Where is the salt?
- **Record:** Explain how you know where all the ingredients are.

12. Clean up your area.

- Follow your teacher's directions.

Picture for Step 8

Picture for Step 9

Picture for Step 10

Picture for Step 11

Salting Out

INSTRUCTION CHART

JAR # 1 Add 4 spoonfuls water	JAR # 2 Add 6 spoonfuls alcohol
JAR # 3 Add 4 spoonfuls water	JAR # 4 Add 6 spoonfuls alcohol

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Salting Out

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
small jars with lids (e.g., baby food jars)	4 per group		
masking tape	1 roll per group		
permanent markers (e.g., Sharpie™)	1 per group		
pop-top squeeze bottles (e.g., empty Gatorade™)	2 per group		
isopropyl alcohol (at least 90% concentration; 99% or more is best)	½ cup per group		
water	½ cup per group		
salt	¼ cup per group		
plastic cups, 8 oz.	1 per group		
teaspoon measures	2 per group		
8½" x 11" plastic protective sleeves (optional)	1 per group		
sponges and towels for clean up			
Extension A			
M&M's™, Skittles™, or another candy with water soluble dye	4 per group		
Extension B			
dyes of unknown solubility: dry erase markers, overhead pens, colored markers, squares of paper with color printed from a computer, candies	varies		
Extension C			
rulers	1 per group		
extra alcohol	¼ cup per group		
extra water	¼ cup per group		
extra salt	¼ cup per group		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Teacher Demonstration			
Oil and Water			
clear plastic bottle with lid (20 oz., 1 liter, etc.) or clear jar with lid	1 per class		
food coloring, any color	1 bottle (only a few drops needed)		
vegetable oil	about ¾ cup or more		
Oil, Water, and Soap			
bottle of liquid dish or hand soap	a few squirts from the bottle		
Otherwise, supplies are the same as for the teacher demonstration with oil and soap.			

Un Arco Iris de Densidad

PROCEDIMIENTO CIENTÍFICO

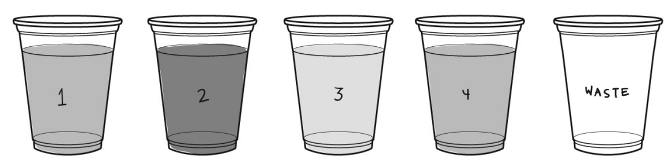
1. Marca cuatro vasos con números del #1 al #4. Identifica otro vaso con la palabra “Desechos”.

2. Llena de agua hasta la mitad los vasos con los números del #1 al #4. Agrega azúcar a cada vaso de acuerdo a la tabla de la derecha.

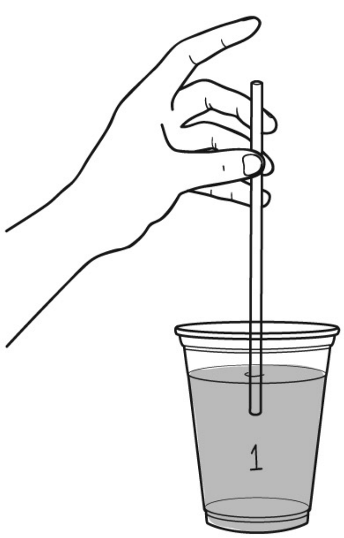
3. Llena de agua los vasos del #1 al #4 para que se vean como en el dibujo. Agrega colorante al agua de cada vaso siguiendo la tabla de la derecha.

4. Revuelve el agua hasta que se haya disuelto todo el azúcar.

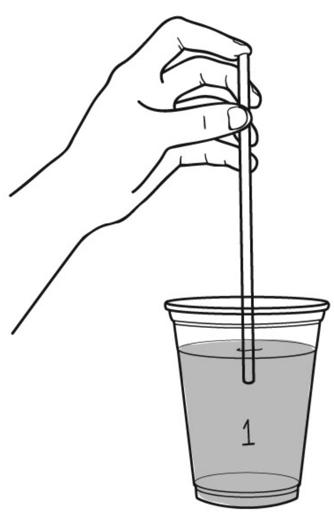
Vaso	Azúcar (cucharadas)	Color (4 gotas)
1	1	Rojo
2	2	Azul
3	3	Amarillo
4	4	Verde



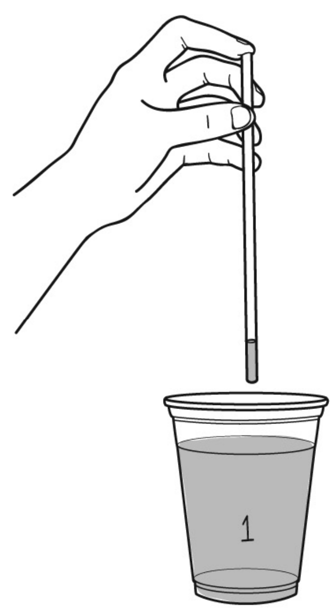
5. Contén una cantidad del líquido rojo en el popote (pajilla, pitillo), como se muestra a continuación:



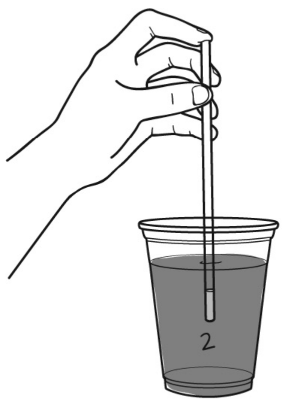
Sumerge el popote ½ pulgada.



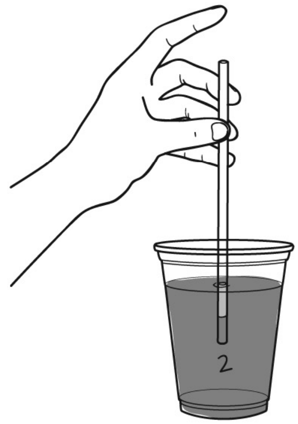
Sella el extremo superior con tu dedo…



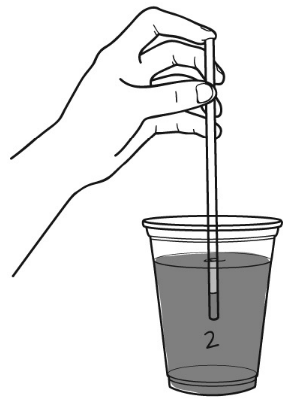
…ahora saca el popote del vaso. ¡No quites el dedo!



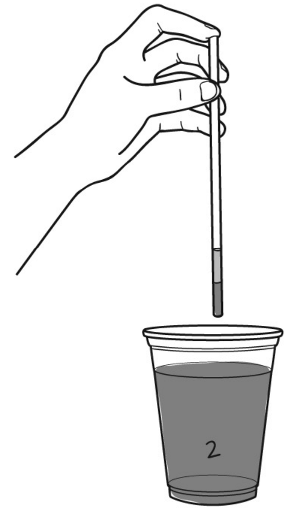
Mantén tu dedo en el popote y sumérgelo en el próximo vaso.



Levanta tu dedo para que entre la otra solución.



Ahora coloca tu dedo de nuevo en el popote…



…y saca el popote del vaso.

6. Ahora contén una cantidad de líquido azul en el popote (pajilla, pitillo) como se muestra a continuación:

- ¿Qué sucedió? ¿Se mezclaron los colores o permanecieron separados?

7. Continúa este procedimiento con el resto de los vasos que contienen agua coloreada. Recuerda que debes colocar el popote (pitillo, pajilla) de tal manera que el líquido dentro del mismo quede por debajo del nivel del agua del vaso. De otra manera no entrará más agua en el popote.

- ¿Qué sucedió? ¿Se mezclaron los colores o permanecieron separados?

8. Vacía el contenido del popote en el vaso de los desperdicios.

9. Intenta agregar los colores en un orden diferente. Experimenta con muchas combinaciones diferentes.

- ¿En qué orden se mezclan más los colores?

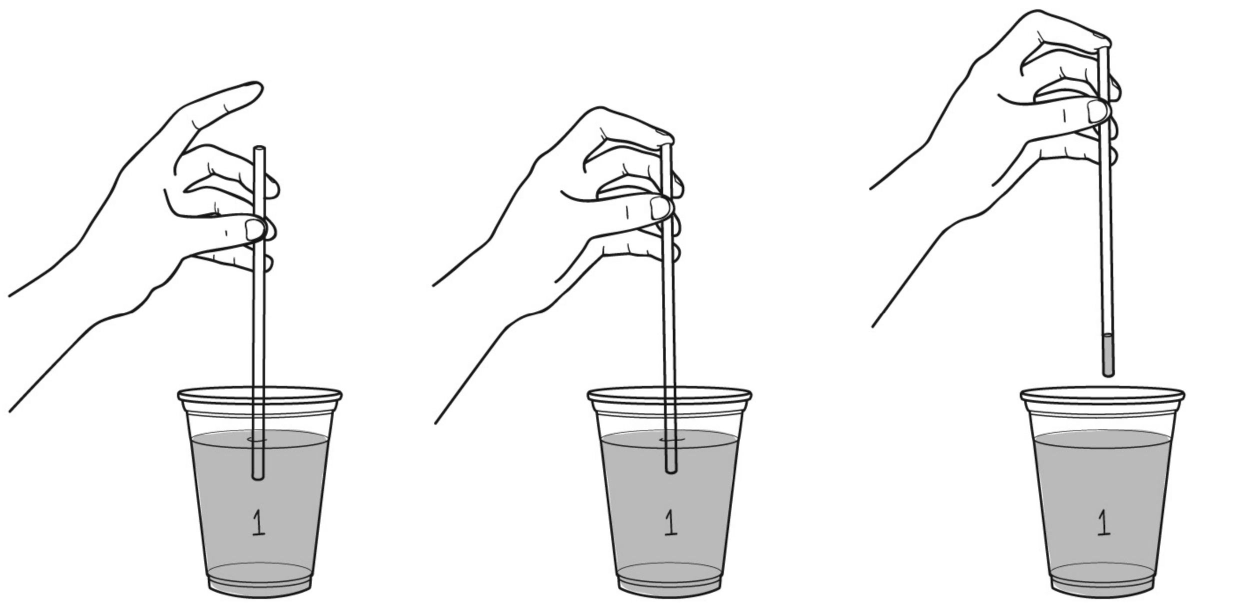
- ¿En qué orden se mantienen separados los colores?

10. Limpia tu área de trabajo.

- Sigue las instrucciones de tu maestro(a).

Haciendo un Arco Iris de Densidad

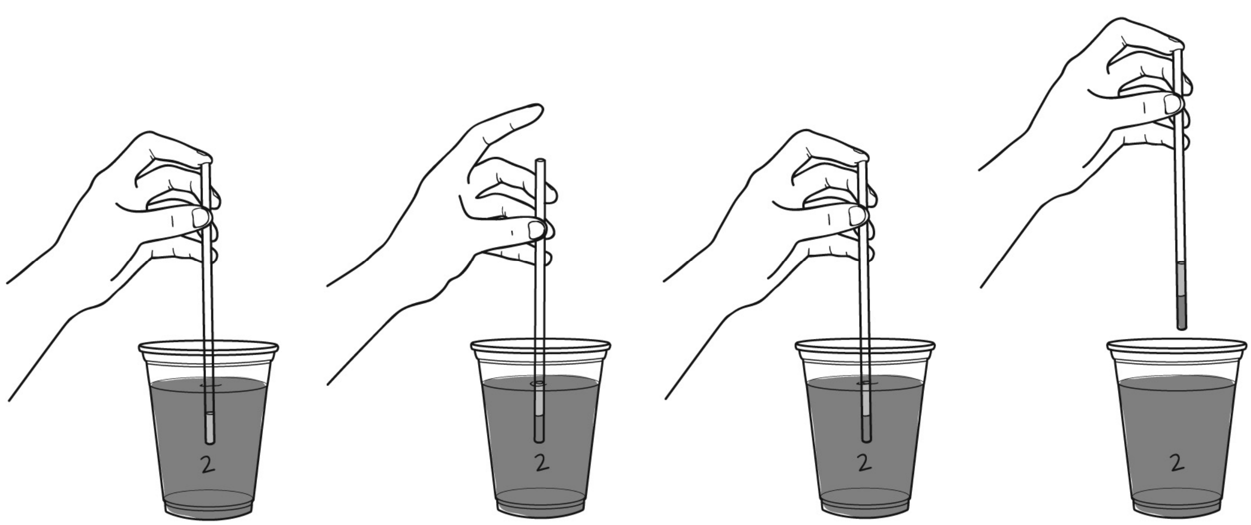
La ilustración detallada del procedimiento con el popote



Sumerge el popote ½ pulgada.

Sella el extremo superior con tu dedo…

…ahora saca el popote del vaso. ¡No quites el dedo!



Mantén tu dedo en el popote y sumérgelo en el próximo vaso.

Levanta tu dedo para que entre la otra solución.

Ahora coloca tu dedo de nuevo en el popote…

…y saca el popote del vaso.

Un Arco Iris de Densidad

PROCEDIMIENTO CIENTÍFICO
Para las EXTENSIONES B o C

1. Elige un líquido. Escribe el nombre del líquido en la columna A de la Tabla de Datos.

2. Mide la masa de un envase vacío utilizando una pesa o balanza. Escribe el resultado de la masa en la columna B de la Tabla de Datos. Recuerda escribir las unidades correspondientes a la medida.

3. Con cuidado mide al menos una cucharada (15 mililitros) del líquido. Escribe el volumen del líquido en la columna E de la Tabla de Datos.

   Recuerda escribir las unidades correspondientes a la medida.

4. Agrega el líquido en el envase que acabas de pesar.

5. Escribe la masa tanto del líquido como del envase en la columna C de la Tabla de Datos.

6. Calcula la masa del líquido. Para hacerlo, resta el valor de la columna B al valor de la columna C. Es decir:

   masa del envase con el líquido- masa del envase= masa del líquido

   Recuerda escribir las unidades correspondientes al valor en la Columna D.

7. Calcula la densidad del líquido. Para hacerlo, divide la masa del líquido entre el volumen del líquido. Es decir:

$$\text{densidad} = \frac{\text{masa del líquido}}{\text{volumen del líquido}}$$

   Recuerda escribir las unidades correspondientes al valor en la Columna F.

8. Repite los pasos del 1 al 6 con todos tus líquidos y escribe los valores en la Tabla de Datos.

9. Limpia tu área de trabajo.
   - Sigue las instrucciones del maestro(a).

Arco Iris de Densidad

TABLA DE DATOS

Para las EXTENSIONES B o C

A	B	C	D	E	F
Nombre del líquido	Masa del envase	Masa del envase con el líquido	Masa del líquido	Volumen del líquido	Densidad

Arco Iris de Densidad

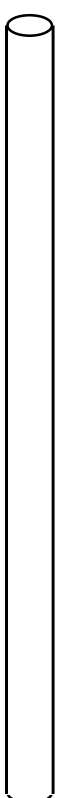
HOJA DE DATOS

Colorea un dibujo de tu popote (pitillo, pajilla) cada vez que lo llenes de líquidos. Además de cada dibujo, escribe el orden en que agregaste los colores al popote.

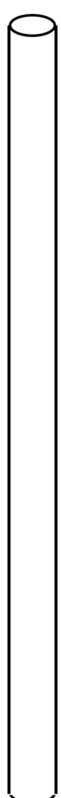
- ¿Permanecieron en el orden que los agregaste?

- ¿Se mezclaron?

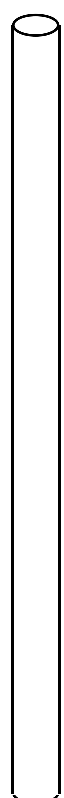
Notas:



Notas:



Notas:



¿Más masa en la taza?

PROCEDIMIENTO CIENTÍFICO

1. Escribe en tres vasos "canicas," "agua salada," y "agua con arena."
2. Llena completamente el vaso identificado como "canicas" con canicas.
   - *¿Cómo sabes que el vaso está lleno?*
   - *¿Crees que puedes agregar arena a este vaso? ¿A dónde iría la arena si la agregaras?*

3. Agrega arena al vaso identificado como "canicas."
   - *¿Cuántas cucharadas de arena puedes agregar en el vaso de canicas?*
   - *¿A dónde fue la arena?*
4. Llena completamente los vasos identificados como "agua salada" y "agua con arena" con agua.
   - *¿Cómo sabes que los vasos están llenos?*
   - *¿En qué se parecen los vasos llenos de agua al vaso lleno de canicas?*
5. En el próximo paso agregarás arena al vaso identificado como "agua con arena" hasta que el agua se desborde.
   - **Predice**: *¿Cuántas cucharadas de arena crees que puedes agregar al agua?*

6. Con cuidado agrega una cucharada de arena al vaso de "agua con arena". Agrega y cuenta más cucharadas de arena.

- ¿Cuántas cucharadas de arena pudiste agregar en el agua?
- ¿A dónde fue la arena?

7. En el próximo paso agregarás sal al vaso identificado como "agua con sal" hasta que el agua se desborde.

- **Predice:** ¿Cuántas cucharadas de sal crees que puedes agregar?

8. Ahora agrega una cucharada de sal al vaso de "agua con sal". Agrega y cuenta más cucharadas de sal.

- ¿Cuántas cucharadas de sal pudiste agregar en el agua?
- ¿A dónde fue la sal?

9. Limpia tu área de trabajo.

- Sigue las instrucciones de tu maestro(a).

Cambiando Gradualmente

PROCEDIMIENTO CIENTÍFICO

1. Marca una bolsa de plástico con la letra "D" para el detergente. La otra bolsa identifícala con la letra "E" por sal de Epsom.

2. Agrega tres cucharadas de agua en cada bolsa.
    - Toca las bolsas. ¿Cómo se sienten?

3. Agrega una cucharada de detergente en la bolsa identificada con la letra "D". Sella la bolsa y con cuidado mezcla los ingredientes apretando la bolsa por 30 segundos.
    - ¿Cómo se siente ahora la bolsa?

4. Agrega una cucharada de sal de Epsom en la bolsa identificada con la letra "E". Sella la bolsa y con cuidado mezcla los ingredientes apretando la bolsa por 30 segundos.
    - ¿Cómo se siente ahora la bolsa?

5. Compara las dos bolsas.
    - ¿En qué se parecen los contenidos de las dos bolsas?
    - ¿En qué son diferentes los contenidos de las dos bolsas?

6. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

Con un poquito de sal

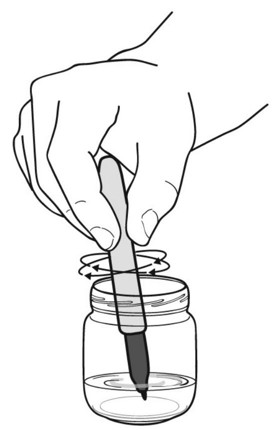
PROCEDIMIENTO CIENTÍFICO

1. Utilizando cinta adhesiva, marca dos cucharas, una como "líquido" y la otra como "sal." Identifica también cuatro frascos con los números del #1 al #4. Coloca los frascos sobre el Gráfico de Instrucciones.

2. Mira el Gráfico de Instrucciones y agrega agua o alcohol a los frascos de acuerdo a las instrucciones.

3. En el siguiente paso vas a agregar sal en el Frasco 1 y en el Frasco 2. Pero antes de hacerlo:
    - Predice: ¿Crees que la sal se disolverá en el agua?
    - Predice: ¿Crees que la sal se disolverá en el alcohol?

4. Ahora, agrega una cucharada de sal al Frasco 1 y al Frasco 2. Colócales las tapas y agítalos por 20-30 segundos.
    - Registra: Describe cómo se ven la sal y el agua.
    - Registra: Describe cómo se ven la sal y el alcohol.



5. Coloca a un lado los Frascos 1 y 2.

6. En el próximo paso vas a agregar tinta permanente a los Frascos 3 y 4. Pero antes de hacerlo:
    - Predice: ¿Crees que la tinta se disolverá en el agua?
    - Predice: ¿Crees que la tinta se disolverá en el alcohol?

7. Ahora, coloca la punta del marcador permanente en el líquido del Frasco 3 y revuelve por 10 segundos. Repítelo con el Frasco 4. Cuando termines colócale la tapa al marcador. Colócales las tapas a los frascos y revuélvelos por 5 segundos.
    - Registra: Describe cómo se ven la tinta y el agua.
    - Registra: Cómo se ven la tinta y el alcohol.

8. En el próximo paso (pero no todavía), vas a mezclar el contenido del Frasco 4 con el del Frasco 3. Antes de hacerlo, ¿qué crees que sucederá?
   - Predice: Dibuja y nombra cómo crees que se verá la mezcla. ¿Dónde estará el agua? ¿Dónde estará el alcohol? ¿Dónde estará la tinta?

Dibujo para el paso 8

9. Ahora, vierte el alcohol del Frasco 4 en el agua del Frasco 3. Colócale la tapa al frasco y revuelve por 5 segundos para que se mezcle.

   - Registra: Dibuja y nombra la mezcla. ¿Dónde está el agua? ¿Dónde está el alcohol? ¿Dónde está la tinta?
   - Registra: Explica cómo sabes dónde están todos los ingredientes.

Dibujo para el paso 9

10. En el próximo paso, le vas a agregar sal a la mezcla. Antes de hacerlo, ¿qué crees que sucederá?
   - Piensa: Lee tus resultados hasta ahora.
   - Predice: Dibuja y nombra cómo crees que se verá la mezcla después de agregar la sal. ¿Dónde estará el agua? ¿Dónde estará el alcohol? ¿Dónde estará la tinta? ¿Dónde estará la sal?

Dibujo para el paso10

11. Ahora, agrega una cucharada de sal a la mezcla del Frasco 3. Colócale la tapa al frasco y agítalo de 20 a 30 segundos.
   - Registra: Dibuja y nombra la mezcla. ¿Dónde está el agua? ¿Dónde está el alcohol? ¿Dónde está la tinta? ¿Dónde está la sal?
   - Registra: Explica cómo sabes dónde están los ingredientes.

Dibujo para el paso 11

12. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Con un poquito de sal

GRÁFICO DE INSTRUCCIONES

FRASCO # 1 Agrega 4 cucharadas de agua	**FRASCO # 2** Agrega 6 cucharadas de alcohol
FRASCO # 3 Agrega 4 cucharadas de agua	**FRASCO # 4** Agrega 6 cucharadas de alcohol

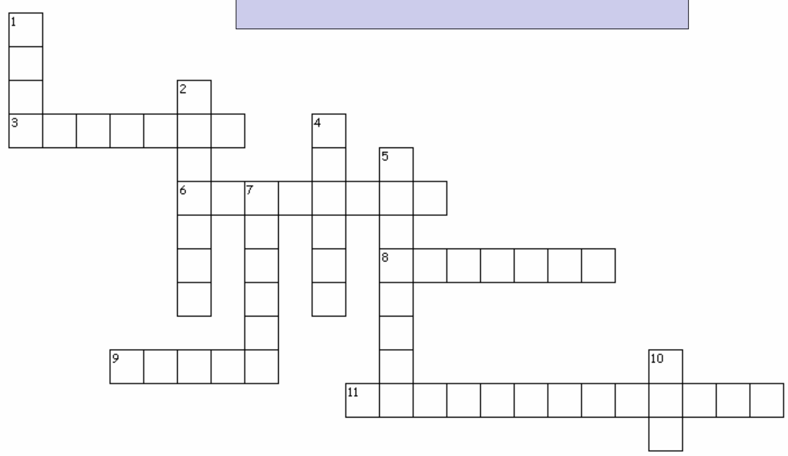
Concepts

All matter is made of chemicals, which can be found in different forms.

Words to know

atom - a very, very small particle that makes up all matter.
chemical bond - a connection that holds two atoms together.
compound - a substance made of two or more elements chemically bonded together.
crystal - a solid that has a regular pattern of atoms or molecules.
density - a description of how tightly packed the molecules are in substance.
electron - a negatively charged part of an atom.
element - a substance made of all the same type of atoms.
gas - a state of matter in which the molecules or atoms are very far apart; can take any size and shape.
liquid - a state of matter in which the molecules or atoms are close together; has constant size but can take any shape.
matter - anything that has mass and occupies space.
miscibility - the ability of two substances to dissolve together.
mixture - two or more elements or compounds that are mixed together but are not chemically bonded.
molecule - a group of at least two atoms held together in a definite arrangement.
periodic table - a chart that groups the elements by similar properties and structures.
physical state - the form a substance takes based on the behavior of its molecules or atoms: solid, liquid, or gas.
solid - a state of matter in which the molecules or atoms are close together; has constant size and shape.
solution - a completely uniform mixture.
solubility - the ability of a substance to dissolve in another substance.

Use the clues and the Words to Know to complete the crossword puzzle.



Across

3. A soft drink is a _____ of carbon dioxide gas and liquid since the gas and liquid are not chemically bonded together.
6. When salt is dissolved in water, it forms a _____.
8. Carbon is an _____, a substance made of the same type of atoms.
9. Three states of matter are _____, liquid, and gas.
11. A chart that groups elements by similar properties is called the _____ _____.

Down

1. An _____ is a very, very small particle.
2. A diamond is a _____, a solid that has a regular pattern of atoms.
4. _____is anything that fills space and has mass.
5. The formula NaCl shows the elements that are in a _____ of table salt.
7. Water is a _____; it has a constant size but can change its shape.
10. Helium is a _____; its molecules spread out to fill a space.

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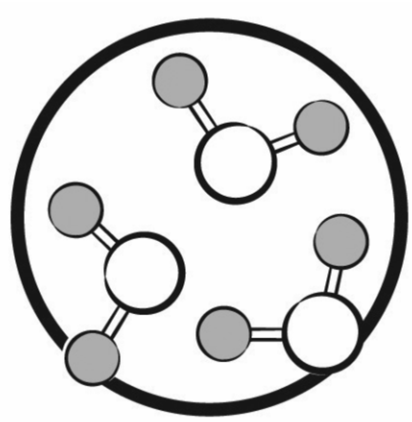
ChemLab

Take-Home Activities



The Nature of Matter

Density

Make a golf ball float!

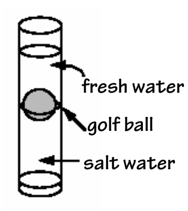
Materials:

golf ball
water
salt
a tall, thin, transparent container slightly larger than the golf ball, for example a vase
food coloring
mixing container
stirring spoon
masking tape
pen

To do and notice:

1. Fill the tall container half full with water and pour it into the mixing container.

2. Place the golf ball into the mixing container. Notice that it sinks. Stir salt into the water until the ball floats.



3. Take the golf ball out and put it into the tall container. Pour the salt solution into the tall container.

4. Add fresh water to the mixing container. (Add enough to fill the top half of the tall container.) Add 4 drops of food coloring.

5. Slowly add the colored fresh water to the tall container until it is full.

6. With a piece of masking tape and a pen, mark the height of the ball in the container.

A closer look:

The golf ball is not as dense as the saltwater. Therefore, the ball floats on top of the saltwater. The colored fresh water is not as dense as the golf ball, so the ball sinks in the colored water. Eventually, the saltwater and the colored fresh water mix. As the waters mix, the ball will sink.

Crystals

Grow your own garden!

Materials:

small piece of porous brick or charcoal briquette
1 tablespoon liquid bluing (in the laundry section of a grocery store)
1 tablespoon ammonia
1 tablespoon salt
2 tablespoon water
shallow dish
magnifying glass (optional)

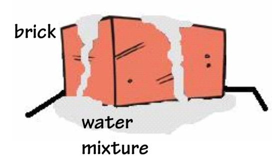
To do and notice:

1. Place the brick in the dish.

2. Mix the bluing, ammonia, salt, and water until they are thoroughly combined.

3. Pour the water mixture over the brick.

4. Let the dish stand undisturbed for three or four days. Make daily observations.
   - **What do you see?**
   - **When did crystals appear?**



5. Observe the crystals with a magnifying glass.
   - **What do the crystals look like?**

A closer look:

The brick acts as a wick, soaking up the liquid in the dish. Crystals form as water evaporates from the surface of the brick, leaving the chemicals behind. The chemicals form crystal patterns.

Now try this with a different batch:

Add food coloring to the liquid mixture.
- Are the crystals colored?

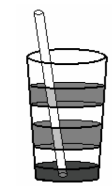
Layered Liquids

Chemistry you can drink?

Materials:

a tall, clear glass
ice
Sprite, 7UP, or other clear soda
chocolate syrup
grenadine (optional)
whipped cream
maraschino cherry
a straw

To do and notice:



1. Carefully add all the soda, syrup, grenadine, and whipped cream to the glass. Let the glass stand a few moments.
   - **Which layers rise to the top?**
   - **Which settle to the bottom?**

2. **Where do you think the cherry will float?** Drop it in and see.

3. Draw a picture of the layers in the glass.

4. Stir the glass with the straw and let it stand for a few moments.
   - **Do the layers mix?**
   - **Do they stay separate?**

5. Drink your experiment!

A closer look:

Density describes how tightly packed a substance is. The more material that is packed in a space, the more dense it is. If there is a lot of space between molecules, the substance is not as dense. The molecules of a denser liquid, like chocolate syrup, are arranged more compactly than are the molecules of a liquid with less density, like 7UP. This is why the chocolate syrup sinks to the bottom and the 7UP rises to the top.

Color Me Blue

Learning Objectives: *Students use a chemical reaction (bleaching) to identify the components in a mixture.*

GRADE LEVEL

4–8

SCIENCE TOPICS

Atoms and Molecules
Techniques
Chemical Reactions

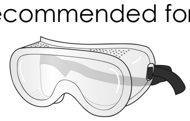
PROCESS SKILLS

Predicting
Controlling Variables
Inferring

GROUP SIZE

2–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students use bleach to change the color of food color solutions.

STUDENT SUPPLIES

see next page for more supplies

blue, green, and lemon yellow food coloring
bleach solution
plastic pipettes or eyedroppers, etc.…

ADVANCE PREPARATION

see next page for more details

Mix bleach solution
Mix food coloring solutions, etc.…

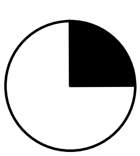
OPTIONAL EXTRAS

DEMONSTRATION
Bleach and Dyed Fabrics (p. B - 5)

EXTENSIONS
Inquiry Opportunity—Concentration (p. B -10)
Suspicious Green (p. B - 10)
Dye Chromatography (p. B - 11)

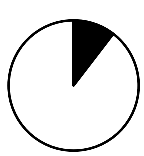
TIME REQUIRED

Advance Preparation



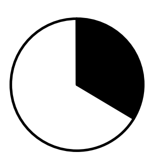
15 minutes

Set Up



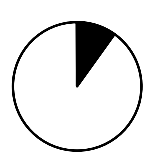
5 minutes

Activity



20 minutes

Clean Up



5 minutes

SUPPLIES

Item	Amount Needed
clear plastic cups, 8 oz.	3 per group
blue, green, and lemon yellow food coloring (must be lemon yellow, not egg yellow coloring)	1 tsp each, per class
plastic spoons	1 per group
EITHER—eyedroppers or disposable plastic pipettes **AND—**small plastic cups or jars to hold food coloring **OR—**small dropper bottles (by themselves)	3 per group—or share several among the class
pop-top squeeze bottles (e.g., water bottles)	1 per group
liquid bleach	less than ⅛ cup per class
teaspoon measure	1 per teacher

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Bleach solution:

- Add about 10 drops of bleach (sodium hypochlorite solution) to 4 cups of water.
- Fill each pop-top squeeze bottle with at least ¼ cup of dilute bleach solution.
- Label the bottles "bleach."
- **Note:** If you are using one of the student eyedroppers to make the bleach solution, rinse it out well with water before passing it on to students.

CAUTION: Bleach is poisonous and hazardous to eyes, skin, and the respiratory tract. Handle with caution. Never mix bleach with other household cleaners, as it may release toxic gases. Wear gloves and use care when handling.

Blue and yellow food coloring solution:

- For each color, add 1 teaspoon of food coloring to 1 cup of water.
- Be sure to use lemon yellow coloring, <u>not</u> egg yellow.
- Fill a blue and yellow dropper bottle for each group (or, if such bottles are hard to come by, share several among the entire class).
- Alternatively, fill small jars with the food coloring and pass out eyedroppers or disposable plastic pipettes.

Green food coloring solution:

- ❑ Add 2 teaspoons of food coloring to 1 cup of water.
- ❑ Fill a green food coloring dropper bottle for each group.

Notes and Hints

- ❑ **Yellow food color**: Be sure to use **lemon** yellow food coloring, rather than egg yellow. Lemon yellow food coloring is FD&C yellow #5, while egg yellow coloring is FD&C yellow #6, which will not react with dilute bleach.
- ❑ **Green food color**: Most green food coloring is made with a combination of FD&C blue #1 and FD&C yellow #5. Do not purchase food coloring made with FD&C Green #3 (which is rarer).
- ❑ **Bleach:** Bleach breaks down very quickly in light or heat and so should be stored in a cool, dark place. Test the bleach on the coloring solutions right before class to make sure they are the right concentration.
- ❑ **Eyedroppers or pipettes:** Students with nimble fingers and experience with straws can use them to add food coloring, drop by drop, to the cups. Otherwise use eyedroppers or pipettes.

SETUP

For each group

- ❑ 3 small clear jars or plastic cups
- ❑ spoon
- ❑ squeeze bottle of dilute bleach solution
- ❑ **EITHER—**dropper bottles of blue, green, and yellow food coloring solution (or share these among the class)
  OR—small plastic cups with each food color and eyedroppers (these can also be shared among the class if supplies are tight)

At a central location (or with the teacher)

- ❑ towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

This activity has a somewhat complicated design. Discuss with students why all the steps in the procedure are necessary.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

Students test the effects of dilute bleach on different food colorings and also see that some colors are made up of combinations of other colors.

Today we are going to use one of the most "dangerous" chemicals in the home: bleach! What do you use bleach for?
Making white clothes whiter (cleaner), removing stains from sheets, washing floors, disinfecting toilets and bathtubs, etc.

CAUTION: Full strength bleach is a corrosive and hazardous substance. Wear gloves and use care when handling.

Use this opportunity to tell students about dangerous chemicals in the home. Bleach is famous for its reaction with ammonia (another household cleaner). Mixing bleach and ammonia together creates poisonous chlorine gas.

Even though we are using household materials, remind students to get permission from adults before using materials at home for science experiments.

People are careful to use bleach on white clothes. But what does it do to colored clothes? Has anyone ever gotten bleach on your regular clothes?
Bleach makes whites whiter, but it may react chemically with the dyes in other clothes, turning them white or to a different color: orange, yellow, or even blue!

Sometimes colors are mixtures of one or more other colors. Can anyone give me an example of a color that is a mixture of one or more colors?
All of the secondary colors can be formed by mixing two or more primary colors together (e.g., green can be made by mixing yellow and blue).

TEACHER DEMONSTRATION

Bleach and Dyed Fabrics

Bleach is a powerful color-changing agent, but it reacts differently with each dye (color) that is used in modern textile manufacture. This demonstration shows students the variability and power of bleach.

Supplies

- full strength bleach
- eye dropper or pipette
- variety of fabric samples, 2 inches by 2 inches

Notes and Hints

- Fabric stores (or teachers who sew or quilt) may have many scraps of different colors.
- Cotton fabrics or cotton and polyester blend fabrics work best for this demonstration. Include a variety of colors and patterns.
- Include a white piece of fabric with a grass or food stain on it.
- Test your fabrics before demonstrating in front of the class.

Demonstration

- Ask students to hypothesize what effect bleach will have on several different scraps of clothing.
- Add a drop or two of full strength bleach to the different scraps.
- Some bleaching reactions may take several minutes to occur.
- Try organizing the fabrics by their reactions to look for trends.

Explanation

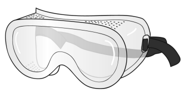
The bleach reacts with some fabric dyes but not others. In fabrics that are printed and dyed, the bleach may remove one or all of the colors while leaving the printed outline of the design behind—a cool effect.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page B - 13, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.



Color Me Blue

SCIENTIFIC PROCEDURE

This handout is on page B - 13.

1. Add two spoonfuls of bleach solution into each of three cups.
2. Add 4 drops of **yellow** food coloring to the first cup. Swirl the cup. Observe it for 30 seconds.
   - What happens to the yellow coloring?

3. In the next step, you will add **blue** food coloring to the second cup. But before you do so:
   - **Predict:** What do you think will happen when you add the blue coloring?
4. Add 4 drops of **blue** food coloring to the second cup. Swirl the cup. Observe it for 30 seconds.
   - What happens to the blue coloring?

Running Suggestions

- Remind students that food coloring will also stain their clothes and their skin.
- Remind students to never mix bleach with other household cleaners, such as ammonia, as it may release toxic gases.
- Students should record their observations as the procedure sheet prompts them. Encourage students to use detail. If a question comes before a step, the student should record their answer to the question BEFORE doing that step.

You may want to instruct students to write their answers on a separate sheet of paper so they will have more space to write.

CAUTION: Even though the bleach solution is very dilute, it will still take the color out of students' clothes.

Ongoing Assessment

- Why did we add yellow coloring to the bleach? How will this help us figure out what bleach will do to green coloring?
- Why did we add blue coloring to the bleach? How will this help us figure out what bleach will do to green coloring?
- Show students the ingredients in the lemon yellow and blue food colorings. Label the green food coloring "unknown coloring." Help them form hypotheses as to how the bleach changes the green to blue.

Safety and Disposal

- If available, students should wear goggles for this activity.
- Dilute bleach and coloring solutions may be poured down the sink.

CAUTION: Bleach is poisonous and hazardous to eyes, skin, and the respiratory tract. Handle with caution. Never mix bleach with other household cleaners, as it may release toxic gases.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Full strength bleach reacts well with dyes in clothes and food stainsto remove the color. However, dilute bleach reacts quickly with only certain types of dyes.

Which colors were changed by the bleach?
The yellow and green food coloring, but not the blue. Yellow became clear, green became blue, and blue remained the same.

Why did the green coloring change colors?
Green is a mixture of yellow #5 and blue #1. The dilute bleach only reacts with the yellow #5, leaving the blue coloring behind.

Are the chemicals that the blue dyes and yellow dyes are made from the same or different?
They are different because they are different colors. The dyes must be different because they react differently to the same amount of dilute bleach.

This activity has a somewhat complicated design. Discuss with students why all the steps in the procedure are necessary.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

EXPLANATION

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

Yellow food coloring reacts with the dilute bleach solution, while blue food coloring does not. Since green food coloring is made of yellow and blue food coloring, adding dilute bleach to it causes it to turn blue. Students use this difference between yellow and blue food coloring to identify the colors in green food coloring.

BACKGROUND FOR ALL GRADES

Chemical Reactions

In **chemical reactions**, substances interact and transform each other; the chemical reaction in this experiment causes a color change. Red and yellow dyes have a structure that is different from blue dyes. Because of this structural difference, dilute bleach reacts with red and yellow dyes but does not affect blue dyes. Green food coloring is just a mixture of FD&C yellow 5 and FD&C blue 1, so when dilute bleach is added the yellow coloring disappears and leaves only blue coloring behind.

Variables and Constants

In a scientific experiment, a **variable** is a part of the experiment that can be changed or altered. In this experiment, students add different colors of food coloring to bleach, so the tested variable is the type of food coloring. This is in contrast to a **constant**, which is a part of the experiment that does not change or cannot be changed. In this experiment, for instance, each container holds the same amount of bleach and the same amount of food coloring. Therefore the amount and dilution of both the food coloring and bleach remain unchanged from container to container. These characteristics of the experiment are "held constant," while only the type of food coloring changes. Sometimes, when scientists hold a variable constant, they say they are "controlling" that variable.

Experimental Design

Chemists often need to find out what ingredients in a mixture are causing a certain chemical reaction. To do this they need to test each ingredient of the mixture separately. Chemists can either separate out all the ingredients of the mixture and test them individually, or they can carry out their tests while changing only one variable at a time.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

In this experiment, students test three different dyes with bleach and compare the results. Students already know that the dyes are different because they are different colors. But since the dilute bleach causes the yellow dye to fade and not the blue dye, they can determine that bleach reacts with only one of the dyes. Since the same bleach solution was used in each reaction, the only difference is the difference in the dyes, so students know any difference in results is due to the difference in the dyes.

When students test the green food coloring, the dilute bleach makes it change to blue. Students can infer that green is made from two colors, yellow and blue. Based on their experience with the previous tests, they can understand that the bleach removed the yellow color but left the blue present.

EXTRA BACKGROUND FOR GRADES 5–8

Dye Composition

Dyes for clothing and food can be split into certain classes of chemicals. The dyes in each class have a similar structure, causing them to react similarly to different influences. One class of dyes is called **azo dyes**. Most yellow and red dyes, including food colorings Yellow 5 and Red 40, are azo dyes. This means that somewhere in the dye molecule there are two nitrogen atoms with a "double bond" between them:

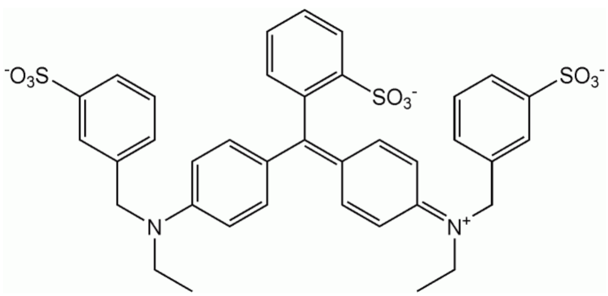


Figure 1. Dye structure for blue food coloring. Notice the lack of a nitrogen-nitrogen bond.

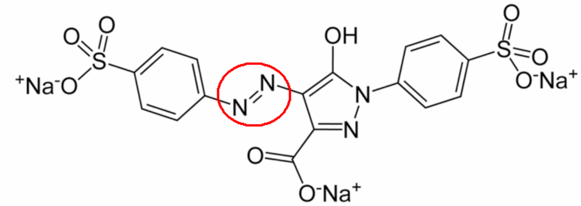


Figure 2. Dye structure for lemon yellow food coloring with the nitrogen-nitrogen bond highlighted.

This nitrogen-nitrogen bond is an essential part of the dye's color. This bond may be particularly vulnerable to the action of bleach—and if the bond is changed or broken, the color of the dye disappears. Blue dyes, on the other hand, get their color from a different bonding pattern. They do not have the nitrogen-nitrogen bond in their structure, and this may explain their resistance to dilute bleach.

Full strength bleach reacts with many dyes in clothes and food stains to remove the color. However, dilute bleach reacts only with certain types of dyes.

Chemistry of Bleach

Liquid bleach is a concentrated solution of sodium hypochlorite (NaClO) in water. By itself NaClO is a solid salt, but when it dissolves in water, it separates into sodium (Na^+) and hypochlorite (ClO^-) ions. The hypochlorite ion is very reactive and causes the decomposition of many organic molecules. In azo dyes, hypochlorite reacts very rapidly with the double bond between nitrogens, breaking the dye molecule in half.

EXTENSIONS

Extension A: Inquiry Opportunity—Concentration
Have students alter the concentration of food coloring and of bleach to explore how it changes the reaction. Make sure they only change one variable at a time, and that they hypothesize about the results before each trial.

Possible Questions:

- How dilute can you make the bleach and still be successful in removing the yellow color?
- How strong does the bleach need to be to remove the blue color?
- How strong can you make the yellow color and still have it bleached out?
- How dilute does the blue color need to be to be bleached out?

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

Extension B: Suspicious Green
Dilute bleach only works on lemon yellow food coloring, not egg yellow. After students have finished the activity (or as an alternative activity), give them several suspicious green solutions and ask them to group them together based on how they react with dilute bleach. Make up a crime scene story or add some other intrigue to the experiment to increase student interest.

Extra Supplies

- egg yellow food coloring (1 tsp per class)
- dropper bottle or eyedropper and plastic cup (1 extra per group)

Extra Instructions

- Mix 1 tsp of egg yellow food coloring with 1 cup of water.
- Mix the egg yellow and blue food coloring together to make a "bleach resistant" green food coloring.
- You can also mix together the lemon yellow and blue food coloring to make the standard green food coloring that will be affected by dilute bleach.

Explanation

Egg yellow food coloring is not an azo dye and is not susceptible to bleaching with dilute bleach.

Extension C: Dye Chromatography

Use chromatography techniques on the yellow, blue, and green food colorings. This will separate the green food color into its component parts, yellow food coloring and blue food coloring.

For general instructions about chromatography, refer to the activity **Dye Detective**.

Extra Supplies

- watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels
- pencil
- tape
- clear, plastic cups (8 oz. or 12 oz.)
- toothpicks
- rubbing alcohol, 70% isopropyl alcohol
- pop-top squeeze bottle (e.g., water or sports drink)

Extra Instructions

- Use a different toothpick to make a small mark of each of the food colorings on the filter paper.
- Since the food coloring is very soluble in water, the 70% isopropyl alcohol works better to separate the dyes in the green food coloring.
- Fill pop-top squeeze bottles with about ¼ cup of rubbing alcohol. Label these bottles "rubbing alcohol."

Explanation

Chromatography is a technique chemists use to analyze mixtures. Different dye chemicals respond differently to the paper and carrier liquid, so travel differently on the paper. The blue and yellow dye molecules are different so travel on the paper differently. When students use yellow, green, and blue dye in the chromatography, they should see blue travel close to the top of the alcohol, and yellow travels more slowly. The green dye should separate into two dye marks; a blue mark even with the mark from the blue dye, and a yellow mark even with the mark from the yellow food coloring.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS **Graph Reaction Rate**
Graph the effect of concentration vs. reaction time for both bleach and food coloring.

LANGUAGE ARTS **Great Laundry Adventure Story**
Write a "tall tale" titled "The Great Laundry Adventure!" Did a scientist discover a super-bleach or a new chemical that removes the effects of bleach—no matter what the original color? Perhaps a young scientist was shrunk down to molecule size—what do colors look like up close?

ART **Bleach Art**
Student can make a design by using a Q-tip to apply bleach to different colors of construction paper.

RESOURCES

Web – http://www.cfsan.fda.gov/~lrd/colorfac.html
The FDA's frequently asked questions about food colors.

VOCABULARY

azo dye: class of food and clothing dyes that contains a nitrogen to nitrogen double bond

chemical reaction: often characterized by a change in color, fizzing

constant: a quantity, value, or condition in an experiment that is fixed or unchanged

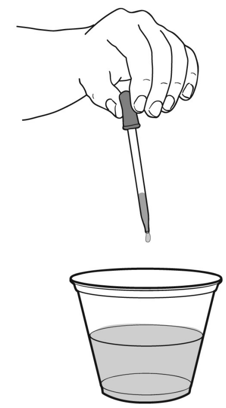
variable: a quantity, value, or condition in an experiment that is changed

Color Me Blue

SCIENTIFIC PROCEDURE

1. Add two spoonfuls of bleach solution into each of three cups.

2. Add 4 drops of **yellow** food coloring to the first cup. Swirl the cup. Observe it for 30 seconds.
   - What happens to the yellow coloring?



3. In the next step, you will add **blue** food coloring to the second cup. But before you do so:
   - **Predict:** What do you think will happen when you add the blue coloring?

4. Add 4 drops of **blue** food coloring to the second cup. Swirl the cup. Observe it for 30 seconds.
   - What happens to the blue coloring?

5. In the next step, you will add **green** food coloring to the third cup. But before you do so:
   - **Predict:** What do you think will happen when you add the green color?
   - **Explain:** What are your reasons for making this hypothesis?

6. Add 4 drops of **green** food coloring to the third cup. Swirl the cup. Observe it for 30 seconds.
   - What happens to the green coloring?
   - Does this experiment confirm your hypothesis? Why or why not?

7. Clean up your area.
   - Follow your teacher's directions.

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Color Me Blue

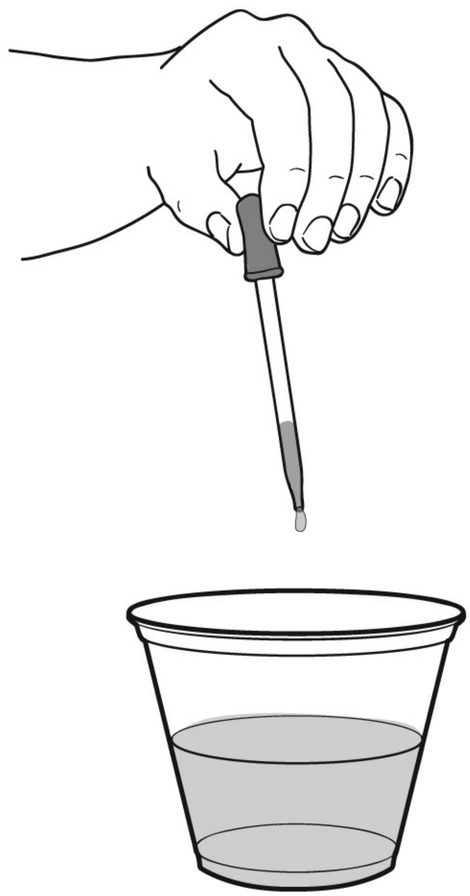
Recommended group size: 2–3

Number of Students: [ ] Number of Groups: [ ]

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
clear plastic cups, 8 oz.	3 per group		
blue, green, and lemon yellow food coloring (must be lemon yellow, not egg yellow coloring)	1 tsp each, per class		
plastic spoons	1 per group		
EITHER—eyedroppers or disposable plastic pipettes **AND—**small plastic cups or jars to hold food coloring **OR—**small dropper bottles (by themselves)	3 per group—or share several among the class		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
liquid bleach	less than ⅛ cup per class		
teaspoon measure	1 per teacher		
towels and sponges for clean up			
Extension A			
substances to attempt to bleach: unsweetened Kool-Aid™ packets, colored fabric squares, colored construction paper, printed paper from a color printer	2–3 items per group		
Extension B			
egg yellow food coloring	1 tsp per class		
additional small dropper bottle	1 per group		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Extension C			
watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels	1 per group		
pencil	1 per group		
tape	1 roll per group		
clear, plastic cups (8 oz. or 12 oz.)	1 per group		
toothpicks	3 per group		
rubbing alcohol, 70% isopropyl alcohol	¼ cup per group		
pop-top squeeze bottle (e.g., water or sports drink)	1 per group		
Teacher Demonstration			
full strength bleach			
eye dropper or disposable plastic pipette	1 for teacher		
several samples of fabric, various colors, 2 inch by 2 inch squares	as many as desired		



Of Cabbages and Kings

Learning Objectives: *Students will learn about indicators, acids, bases, and the pH scale.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Physical Properties
Techniques
Chemical Reactions

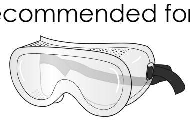
PROCESS SKILLS

Describing and Defining
Classifying
Organizing Data

GROUP SIZE

2–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students use cabbage juice to test for the acidity or basicity of different substances.

STUDENT SUPPLIES

see next page for more supplies

red cabbage
baking soda and/or ammonia
vinegar and/or cream of tartar
plastic cups, etc.…

ADVANCE PREPARATION

see next page for more details

Chop or tear red cabbage
Fill pop-top bottles with vinegar, etc.…

OPTIONAL EXTRAS

DEMONSTRATION

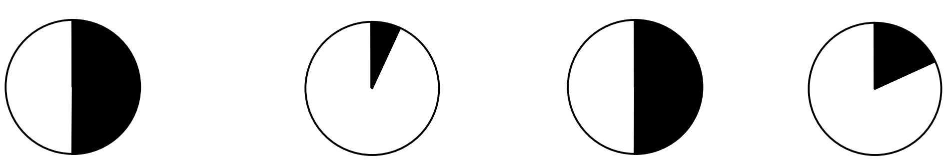
Color Changing Cups (p. B - 22)
Yellow Cabbage Juice (p. B - 23)

EXTENSIONS

Test Household Substances (p. B - 28)
Reverse Color Changes (p. B - 28)
Inquiry Opportunity: Other Plant Indicators (p. B - 29)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
30 minutes	5 minutes	30 minutes	10 minutes



SUPPLIES

Item	Amount Needed
purple cabbage	1 head per class
salt (optional)	½ cup for preparation
knife (optional)	1 for preparation
strainer	1 for preparation
large bowls	2 for preparation
funnel	1 for preparation
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	3 per group
clear plastic cups, 8 oz.	4 per group **and** 4 per student
plastic spoons	2 spoons per group
cream of tartar*	¼ cup per group
baking soda*	¼ cup per group
ammonia*	¼ cup per group
white vinegar*	¼ cup per group
sugar	¼ cup per group
salt	¼ cup per group
cafeteria tray	1 per group

* In a pinch, the activity only requires one acid (cream of tartar or vinegar) and one base (baking soda or ammonia) to make the cabbage juice change color.

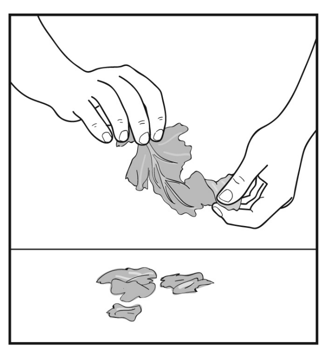
For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

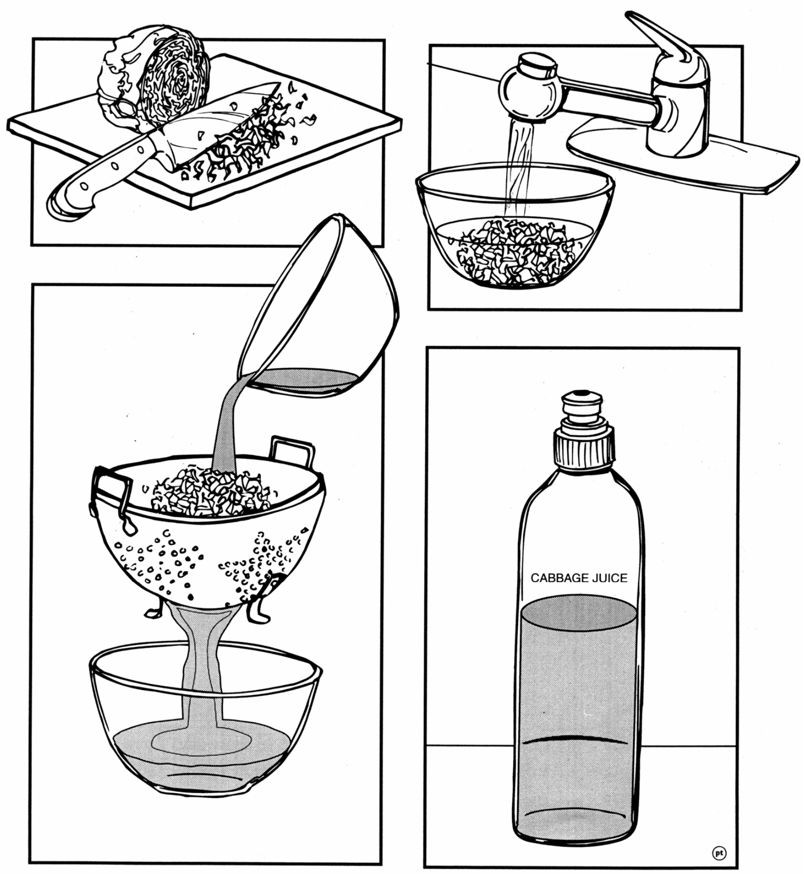
Cabbage juice indicator:

- ❑ Finely chop cabbage with a knife. (Alternatively, have kids tear the cabbage with their fingers.)
- ❑ Place at least 2 cups of cabbage in a large bowl.



Young children can tear cabbage with their fingers.

- 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 into a bowl. The water should now be purple.
- If you want to store the cabbage juice for more than a few hours, add ½–1 cup salt to the mixture and stir until dissolved. Store cabbage juice in refrigerator if it is prepared more than a few hours in advance.
- Dispose of solid cabbage as you would other vegetable scraps.
- Dilute cabbage juice as necessary to have enough for all students. One cabbage can make up to a gallon of cabbage juice indicator.
- Fill pop-top squeeze bottles with about 2 cups of cabbage juice for each group.
- Label the bottles "cabbage juice."



CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Solids to Test

- For each solid the students will test (cream of tartar, baking soda, salt, and sugar) put ¼ cup in a plastic cup for each group.
- Label the cups with their contents.

Liquids to Test

- For each liquid the students will test (vinegar, ammonia) put ¼ cup in a pop-top squeeze bottle.
- Label the bottles with their contents.

CAUTION: Ammonia is irritating to eyes. In case of contact, flush eyes immediately with ample water.

SETUP

For each group

- ¼ cup vinegar in labeled pop-top squeeze bottle
- ¼ cup ammonia in labeled pop-top squeeze bottle
- ¼ cup baking soda in labeled plastic cup
- ¼ cup cream of tartar in labeled plastic cup
- ¼ cup sugar in a labeled plastic cup
- ¼ cup salt in a labeled plastic cup
- two plastic spoons
- 4 plastic cups per student
- two cups cabbage juice in labeled pop-top squeeze bottle
- cafeteria tray

At a central location (or with the teacher)

- paper towels for spill cleanup

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity students test various household ingredients for pH using purple cabbage juice as an indicator.

What are some of the different food groups, or in what ways do we classify foods?
Fruits and vegetables, grains, proteins (meat), dairy (milk, cheese, etc.).

Right, some foods are more similar than others. For instance, many vegetables are green, most nuts are small, and many dairy products are yellow or white. Scientists also put chemicals into different groups. These are the **acid** group, the **neutral** group, and the **basic** group.

What are some examples of acids?
Lemon juice, battery acid, stomach acid, vinegar.
If these are all acids, they must share some characteristics. The only two we can taste are lemon juice and vinegar (the others are too strong for our mouths!). How do lemons and vinegar taste similar?
They are both sour. Acids taste sour to our tongue. Lemons have citric acid, and vinegar has acetic acid.

What are some examples of bases?
Detergent, floor cleaner, drain cleaner, kitchen cleaner.

These are all things we can't taste, but if we could, we might notice they taste bitter. Notice that many cleansers are bases.

Scientists cannot use taste to identify acids and bases, because most chemicals are very poisonous. They use a special class of chemicals called **indicators** for this.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Color Changing Cups
A purple liquid is in a clear container; three other clear containers have a very small amount of clear liquid in the bottom. The purple liquid is poured into the clear liquids, and different colors appear.

Supplies
- four clear containers (~2 cups is a good size)
- cabbage juice indicator from the activity
- vinegar (can substitute lemon juice)
- ammonia (can substitute baking soda dissolved in water)
- water

CAUTION: Ammonia is irritating to eyes. In case of contact, flush eyes immediately with ample water.

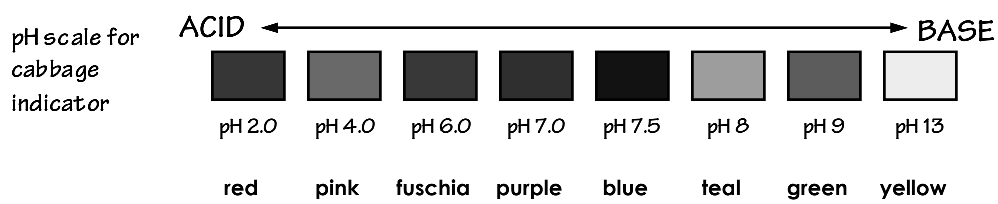
Demonstration
- Prepare four clear containers. Fill one with cabbage juice. In each of the other three, add ~1 tablespoon of vinegar, ammonia, or water. You do not need to remember which container has which colorless liquid.
- Show students a clear container containing cabbage juice indicator and ask them what they think is inside.
- Entertain guesses, but remind students that we only <u>know</u> that it is a liquid and that it is purple.
- Show students three other clear containers holding small amounts (~1 tablespoon) of colorless liquid (one has vinegar, one ammonia, and one water).
- Ask students what they think is in each, and if they think the same ingredient is in each. ("Water" will come up. Clear liquid is a good answer; discuss how not all colorless liquids are water.) Ask the students what they think will happen when you pour the purple liquid into one of the other containers.
- Pour about one third of the cabbage juice into one of the other containers. What happened? What color did it turn?
- Repeat for the other two containers. What happened in those containers?
- What happens when you pour some liquid from one container into another?

At some point, students will encourage you to mix all of the liquids together into one container. If you are using any combination of acids and bases suggested, this will be safe to do. However, if you have chosen baking soda as your base, it will react with vinegar or lemon juice to produce bubbles of carbon dioxide. This may be foamy enough to escape the container. Using vinegar and ammonia does not cause a foaming reaction and can lead to a wide variety of colors in the cabbage juice.

Explanation

Even though three containers all had a small amount of what looked like water, they were not all water. Scientists come across unknown chemicals and chemical mixtures often, and they need to determine their properties. An **indicator** like purple cabbage juice is a good way to discover some properties of unknown chemicals.

The indicator used in this demonstration shows changes in color of acids and bases. Bases turn cabbage juice blue or green; acids turn it red or pink. The water shouldn't change the color of the cabbage juice.



Yellow Cabbage Juice

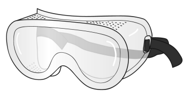
You can make the cabbage juice turn yellow by adding a very strong base. Lye or solid drain opener is strong enough to make the cabbage juice turn yellow. Some liquid drain openers will also work. Test before demonstrating to the class.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page B - 32, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.

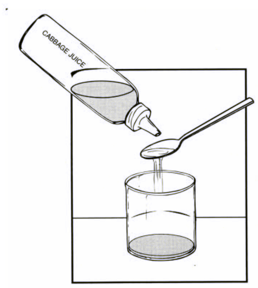


Of Cabbages and Kings

SCIENTIFIC PROCEDURE

This handout is on p. B - 32.

1. Add 2 spoonfuls of cabbage juice to a cup.
   - What does it look like?



2. Add 1 spoonful of baking soda to the cup.
   - What happened?

Running Suggestions

- To control spills, have students do experiments on a cafeteria tray.
- Each group has two spoons they can use. Have them measure dry ingredients with one spoon and wet ingredients with the other.

At some point, students will want to mix all their ingredients into one container. If you are using any combination of acids and bases suggested, this will be safe to do. However, if one of the ingredients is baking soda, it will react with any acid to produce bubbles of carbon dioxide. This may be foamy enough to escape its container.

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Ongoing Assessment Questions

- After students have tested a couple substances, ask them what colors they see.
- Do acids and bases come in different strengths? Or are all acids the same, and all bases the same? How can everyone explain the different types of colors present?
- Ask students to put their reactions in order according to color.

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Liquids can all be poured down the sink with the water running.
- All other materials can be thrown away as solid waste.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Acids and bases are two classifications of chemicals. Indicators, such as cabbage juice, can help us identify what sorts of chemicals are acids and which are bases.

What color is cabbage juice when it reacts with an acid?
Red or pink. HINT: Another name for cream of tartar is tartaric acid.

What color is cabbage juice when it reacts with a base?
Blue or green. HINT: Baking soda is a base.

Which chemicals in our experiment are acids?
Vinegar, cream of tartar, lemon juice, citric acid.

Which are bases?
Baking powder, ammonia, milk of magnesia, antacids, soap flakes.

Have students work in groups to physically arrange the acids and the bases. You may want to show students the pH scale for cabbage juice to help them order their cups from acid to base.

Do all chemicals have to be either an acid or a base? Did you test any chemicals that did not change the indicator?
There are many chemicals that are neither acids nor bases, in this experiment, salt and sugar are both neutral chemicals. In addition, students might point out that adding water does not change the color of the indicator.

When would you want to use an indicator to know if something is an acid or a base?
When identifying unknown substances, or when needing an acid or a base for a specific task (like cleaning your kitchen floor).

EXPLANATION

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

There are millions of chemicals in the universe, all with slightly different properties. To understand this tremendous variety a little better, scientists put chemicals into different families with similar properties

BACKGROUND FOR ALL GRADES

Acids, Bases, and Indicators

Two of the most important families scientists put chemicals into are the **acids** and the **bases**. To find out whether a chemical is an acid or a base, scientists mix it with a color-changing chemical, such as the cabbage juice in this activity, which functions as an **indicator**.

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 do not have appreciable acid or base character. In addition, distilled water is neither an acid nor a base. Such substances are said to be **neutral**.

Indicators are chemicals that turn different colors, depending on whether they are exposed to an acid or a base. Cabbage juice, for instance, can change to either yellow green or blue in bases, and it can change to red or pink in acids.

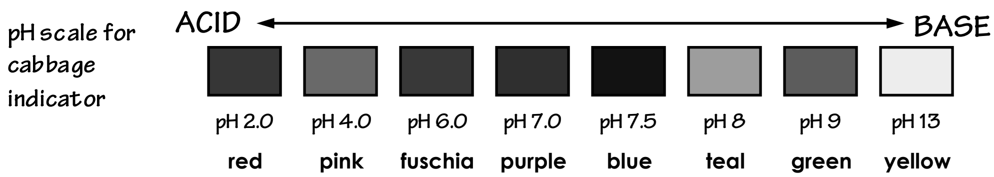
EXTRA BACKGROUND FOR GRADES 6–8

Defining Acids and Bases

Technically, acids are defined as chemicals that release **hydrogen ions** in solution. Bases are called the "opposites" of acids because they are chemicals that tend to take up hydrogen ions.

Not all acids and bases are the same strength. Strong acids and strong bases are both **corrosive** and hazardous because they either release or take up a lot of hydrogen ions. Weak acids and bases release or take up less hydrogen ions, and they are therefore less harmful. For example, stomach acid is a strong acid and is able to eat away concrete by releasing lots of hydrogen ions. Vinegar, on the other hand, is a weak acid that releases much fewer hydrogen ions. It is so weak that if it is accidentally spilled onto skin, it can be safely washed away. (It can be very dangerous in contact with the eyes, however!) Some people even eat this non-poisonous acid on salads, in the form of vinaigrettes.

Defining pH
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:



Plant Indicators
Many times people use a type of chemical called an **indicator** to detect acids or bases. Indicators are usually weak acids or bases that change color when they release or take up hydrogen ions. 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. (See Extension C for hints on how to structure an inquiry investigation into these other indicators.)

Other Indicators
Chemists use a variety of indicators to detect and observe other types of chemicals. For example, some indicators can detect the amount of oxygen dissolved in water. Another indicator can detect the presence of certain metal ions, like the indicator you may use to test paint in your house for lead. Other indicators change color when they release or absorb **electrons**, and so they can help chemists find out how electrons move from molecule to molecule.

Using pH in the "Real World"
As anyone who has taken care of a chlorinated pool knows, the pH of a water solution affects how all the chemicals in it behave. This is because changes in pH can cause changes in molecules (by adding or subtracting hydrogen ions) and in how they react with each other. For instance, if the pH of blood in the lungs is too low (too acid), the protein **hemoglobin** loses some of its ability to pick up oxygen. (This situation can arise in people who climb to extreme heights.)

For another example of how proteins change when exposed to different pH, see the activity **Sticky Situation**.

Similarly, botanists need to know the pH of soil, because many plants grow better in acidic soil, which is common in volcanic places like western Washington and Oregon. Rhododendrons and azaleas, which are very common in these areas, thrive in acidic soil. Some plants, like hydrangeas, have flowers which change color depending on soil acidity. By understanding pH, scientists can learn more about how the world works.

EXTENSIONS

Extension A: Testing Household Substances
Repeat the classroom activity above, substituting or adding additional ingredients. Have students hypothesize which ingredients would be acidic and which ones basic. Students can also bring other chemicals from home to test.

Extra Supplies
- milk of magnesia (¼ cup per group)
- lemon juice (¼ cup per group)
- soap flakes (¼ cup per group)
- laundry detergent (¼ cup per group)
- antacid tablets (1–2 tablets per group)
- Tylenol™ (1–2 tablets per group)
- citric acid or Tang™ (¼ cup per group)
- vitamin C (¼ cup per group)

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by dirty hands or poisons in the lab.

Extension B: Reversing Color Changes
Is the color change caused in cabbage juice reversible? Students can explore this question by adding one of the basic cabbage juice solutions to one of the acid solutions. With some experimentation, they should be able to get the color back to purple. It's easier to start out by mixing only two chemicals. You might discuss controlling variables with the students.

Extension C: Inquiry Opportunity—Plant Indicators

Many plants besides purple cabbage can be used as natural pH indicators. Test other plant extracts/fruit juices for indicator properties.

Extra Supplies

- fruits or berries (blackberry, blueberry, plum)
- flower petals (rose, pansy, petunia)
- grape juice—diluted to half strength
- turmeric powder
- rubbing alcohol (70% isopropyl alcohol)

Extra Instructions

- If using fruits or berries, prepare in the same way as the cabbage juice indicator
- For flower petals, prepare the same way as the cabbage juice indicator. Some more fibrous petals may need to be crushed.
- For grape juice, use the juice half strength or lower to make the color change more apparent.
- Turmeric powder (often found in curry or on its own) contains an acid-base indicator that can dissolve in alcohol. To prepare, mix 1 tsp. turmeric powder with 2 cups of 70% isopropyl alcohol and stir.
- To keep the solutions fresh for more than a couple of days in the fridge, add ½–1 cup salt per quart of indicator.

CAUTION: Isopropyl alcohol is flammable and poisonous. Use care and keep it away from all sparks and flames. It can be flushed down the sink with lots of water.

Explanation

Most plants and juices have the same type of chemical indicator—an **anthocyanin**—as the cabbage juice. Students might notice that the color changes observed in different plants produce similar colors (except for turmeric). For instance, most anthocyanins change color to green upon addition of base.

In turmeric, the indicator curcumin changes color from red to yellow—see the activity ***Reaction: Yes or No?*** for more information on curcumin.

CROSS-CURRICULAR CONNECTIONS

PHYSICS

The Color Wheel
Study the color spectrum, prisms, and rainbows.

HEALTH

Color Test Strips
Research different types of indicators you can find at the store. Some examples are: lead paint tests, diabetes test strips, urinalysis tests, swimming pool test kits, and pregnancy tests.

LANGUAGE ARTS

Alice in Wonderland
The name of this activity, **Of Cabbages and Kings**, is a reference to a poem in the book, *Alice in Wonderland*, by Lewis Carroll. Read this book with your class.

BIOLOGY

Anthocyanins
Anthocyanins are the chemicals that give flowers and plants their pigment. Research how changes in pH affect anthocyanins and why plants would need this function.

The Amazing Stomach
Have students research the mysteries of the stomach. For instance, it contains very strong acid and digestive enzymes designed to break down proteins, fats, etc., but why doesn't it digest itself?

RESOURCES

Web – http://scifun.chem.wisc.edu/chemweek/fallcolr/fallcolr.html
Anthocyanins are responsible for the beautiful reds and oranges in autumn leaves. This site explains the chemistry of these color changes and includes discussions of other colored plant pigments like carotenes and chlorophyll.

Web – http://en.wikipedia.org/wiki/Acid-base_indicator
A good introductory website to the topic, with a list of flowers and plants that contain acid-base indicators.

VOCABULARY

acid: a compound with an excess of available hydrogen ions; often sour in taste

anthocyanin: a class of chemicals found in plants; these chemicals are often responsible for color changes

base: a chemical or compound that takes up hydrogen ions; often bitter in taste

corrosive: causing visible destruction of human skin tissue or able to damage metals or minerals

electron: a tiny negatively charged particle found in atoms and molecules

hemoglobin: the pigment in red blood cells that carries oxygen

hydrogen ion: a hydrogen atom that is missing one electron; often produced by acids and taken up by bases

indicator: a chemical that changes color to show the presence or amount of another chemical

neutral: a chemical that is neither acid nor base and typically has a pH of 7

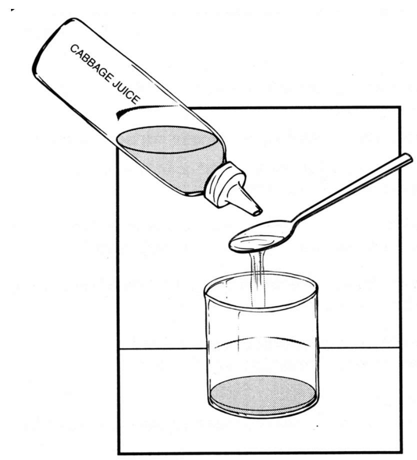
pH: a measure of the acidity or basicity of a solution, numbered on a scale where 1–6 indicates acidic, 8–14 is basic, and 7 is neutral

Of Cabbages and Kings

SCIENTIFIC PROCEDURE

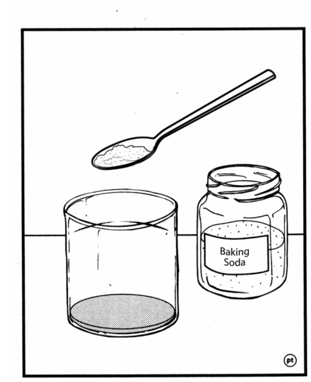
1. Add 2 spoonfuls of cabbage juice to a cup.

- What does it look like?



2. Add 1 spoonful of baking soda to the cup.

- What happened?



- What does the cabbage juice look like now?

3. Test the reaction of other powders and liquids with cabbage juice, and record your observations.

4. Clean up your area.

- Follow your teacher's directions.

Of Cabbages and Kings

DATA SHEET

Record your observations in the table below.

Name of the Chemical Added	Cabbage Juice Color Before	Cabbage Juice Color After	Conclusion: Acid or Base?

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Of Cabbages and Kings

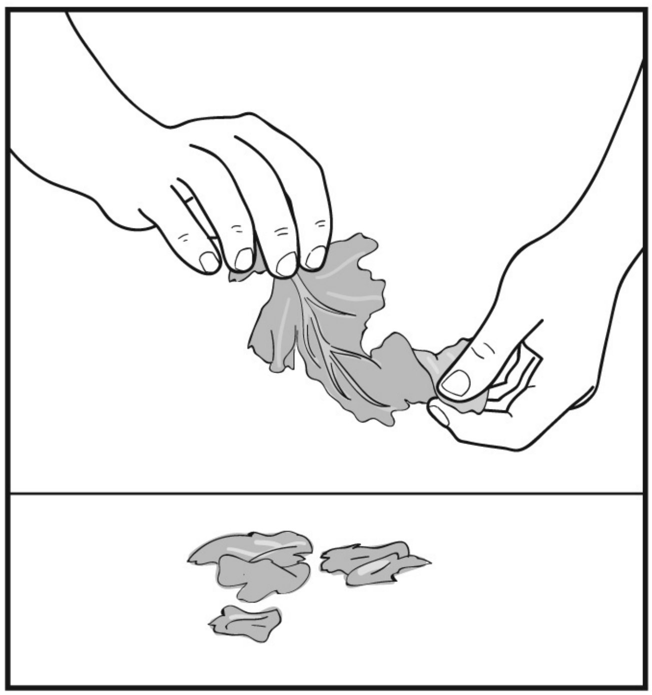
Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
purple cabbage	1 head per class		
salt (optional)	½ cup for preparation		
knife (optional)	1 for preparation		
strainer	1 for preparation		
large bowls	2 for preparation		
funnel	1 for preparation		
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	3 per group		
clear plastic cups, 8 oz.	4 per group **and** 4 per student		
plastic spoons	2 spoons per group		
cream of tartar*	¼ cup per group		
baking soda*	¼ cup per group		
ammonia*	¼ cup per group		
white vinegar*	¼ cup per group		
sugar	¼ cup per group		
salt	¼ cup per group		
cafeteria tray	1 per group		
Extension A			
milk of magnesia	¼ cup per group		
lemon juice	¼ cup per group		
soap flakes	¼ cup per group		
laundry detergent	¼ cup per group		
antacid	1–2 tablets per group		
Tylenol™	1–2 tablets per group		
citric acid or Tang	¼ cup per group		
vitamin C	¼ cup per group		

Supply Worksheet continues on next page.

Extension B			
no additional supplies needed			
Extension C			
fruits or berries (blackberry, blueberry, plum)	1 cup per class		
flower petals (rose, rhododendron, pansy, petunia)	1 cup per class		
grape juice	1 cup per class		
turmeric powder	1 tsp per class		
rubbing alcohol (70% isopropyl alcohol).	2 cups per class		
Teacher Demonstration			
Color Changing Cups			
clear containers (about 2 cup size)	4 for class		
cabbage juice indicator	2 cups		
vinegar (or lemon juice)	1 tablespoon		
ammonia (or baking soda dissolved in water)	1 tablespoon		
water	1 tablespoon		
Yellow Cabbage Juice			
lye or solid drain opener	1–2 tsp per class		
clear container (2 cup size)	1 per class		
cabbage juice indicator	2 cups		



Reaction: Yes or No?

Learning Objectives: *Students will list and identify three characteristics of chemical reactions.*

GRADE LEVEL

3–8

SCIENCE TOPICS

Solutions and Mixtures
Chemical Reactions

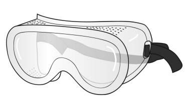
PROCESS SKILLS

Describing and Defining
Measuring
Explaining

GROUP SIZE

1–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students mix household materials and observe color changes, fizzing, and heat.

STUDENT SUPPLIES

see next page for more supplies

turmeric powder,
rubbing alcohol
calcium chloride (from hardware stores)
baking soda
sealing plastic bags, etc….

ADVANCE PREPARATION

see next page for more details

Dilute alcohol with water
Set out plastic cups, etc….

OPTIONAL EXTRAS

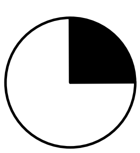
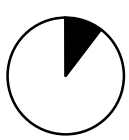
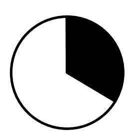
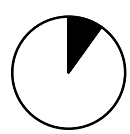
DEMONSTRATION

Acid Base Indicators (p. B - 40)
Gas Production (p. B - 41)

EXTENSIONS

Test Turmeric Indicator (p. B - 46)
De-Icer Product Investigation (p. B - 47)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**5 minutes**	**20 minutes**	**5 minutes**

SUPPLIES

Item	Amount Needed
sealing plastic bag, (e.g., Ziploc™) pint or sandwich size *see Notes and Hints in Advanced Preparation	1 per group
plastic spoons	3 per group
turmeric	1 teaspoon per group
baking soda	¼ cup per group
calcium chloride (available in hardware stores)	¼ cup per group
isopropyl alcohol, 70% (rubbing alcohol) or 90%	< ¼ cup per group
plastic cups, 8 oz.	3 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Dilute isopropyl alcohol solution:

- Dilute 70% or 90% rubbing alcohol to make a 30–35% solution:
  - For 70% isopropyl alcohol (rubbing alcohol), mix 1 part rubbing alcohol to 1 part water (this makes a 35% solution).
  - For 90% isopropyl alcohol, mix 1 part isopropyl alcohol to 2 parts water (this makes a 30% solution).
- Fill pop-top squeeze bottles with about ¼ cup of alcohol.
- Label the bottles "alcohol solution" and write the concentration (30% or 35%).
- Make certain the pop-top is closed on all bottles so the alcohol does not evaporate.

CAUTION: Isopropyl alcohol is flammable at 90% and 70% concentrations. At a concentration of 30%–35%, its flammability is greatly reduced. Nevertheless, all open flames and sparks should always be kept away from these solutions.

Baking Soda:

Fill plastic cups with ¼ cup of baking soda.
Label the cups "baking soda."

Turmeric

- Fill plastic cups with about 1 teaspoon of turmeric powder.
- Label the cups "turmeric."

Calcium Chloride:

- Calcium chloride ($CaCl_2$) is available as a deicer or as a dehumidifier.
  - deicer brands: ComboTherm and Road Runner.
  - dehumidifier brands: Dry Z Air.
  - other brands may work also—look on the side panel and test other brands before using in class.
- Fill plastic cups with ¼ cup of calcium chloride.
- Label the cups "calcium chloride."

CAUTION: Since calcium chloride absorbs moisture from the air, always store calcium chloride in an air-tight container.

Notes and Hints

- Choose higher quality sealing plastic bags with slightly thicker plastic, because upon excessive handling some of the turmeric might diffuse through the plastic onto students' fingers.

SETUP

For each group

- 1 sealing plastic bag, pint or sandwich size
- 3 plastic spoons
- about 1 teaspoon turmeric in a plastic cup
- ¼ cup baking soda in a plastic cup
- ¼ cup calcium chloride in a plastic cup
- ¼ cup diluted alcohol solution in a pop-top squeeze bottle (keep top closed until ready to use)

At a central location (or with the teacher)

- sponges and towels for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

In this activity, students will investigate a simple chemical reaction with easily observable changes.

The most common signs of chemical reactions include the following:

- appearance of a new gas, solid, or liquid
- change in temperature
- appearance of light
- change in color
- change in pH
- production of electricity

Choose questions that are appropriate for your classroom.

What do you think of when you hear the word "chemistry"?
Explosions, foaming and bubbling potions, messy science, mixing things together, etc.

Yes, chemistry is the study of matter (stuff) and how it reacts with other matter (stuff). When two things react together in a chemical way, they change each other, and the results can be quite dramatic (e.g., explosions, color changes, etc.).

Can anyone list some specific examples of chemical reactions?
Student answers will vary depending on exposure to chemistry. Students might suggest fires, batteries, baking soda and vinegar, pH test kits for pools or hot tubs, bleaching hair, cooking food, rusting, gasoline in car engines, medical test strips used by family members (e.g,. for diabetes), etc. It's not critical that students correctly identify reactions at this point, but rather that they use what they know to make a list.

Those all sound like chemical reactions, but how can we be sure? Let's just guess and make a list of what we think are signs of a chemical reaction using these examples.
Some will say things explode or change color. Others might point out that heat is involved. You might ask students to list some real life examples of chemical reactions. Students can come up with their own list of signs of a chemical reaction and test it against the reaction in this experiment.

In this experiment, students will perform and analyze a real chemical reaction.

TEACHER DEMONSTRATION

Acid Base Indicators
This demonstration shows how the turmeric changes color in acids and bases. Because it changes color in different solutions, turmeric is an **indicator** for acids and bases.

Supplies
- 2 clear plastic cups, 8 oz. or larger
- 30% or 35% alcohol solution from the activity
- turmeric powder
- 1 tablespoon vinegar
- 1 teaspoon baking soda

Demonstration
- Add about ¼ cup alcohol solution to each cup. Add a pinch of turmeric powder to each cup and stir until it dissolves.
- Add 1 tbsp. vinegar to one cup of indicator, and then add 1 tsp. baking soda to the other. The turmeric turns red with baking soda but stays yellow with vinegar.

Students will no doubt ask that you pour them together. You can safely mix these together and demonstrate the reaction of baking soda and vinegar by performing the "Gas Production" demonstration below.

Explanation

Turmeric (and curry powder, which contains turmeric) is an acid base indicator. When it reacts with bases (like baking soda), it changes color to deep red. This red form of the indicator can change back to yellow when acids are added. Thus the color of the chemical "indicates" the presence of an acid or base.

Alternatively, use the cabbage juice indicator from **Of Cabbages and Kings** with vinegar and baking soda; it will change to two different colors.

Gas Production

This demonstration shows the fizzing reaction (i.e., the production of gas) that occurs when baking soda is added to vinegar.

Supplies

- 1 tsp. baking soda
- ¼ cup vinegar
- 12 oz. plastic cup

Demonstration

Add the teaspoon of baking soda to the vinegar in the cup. The solution fizzes and pops as the chemicals react and produce carbon dioxide gas.

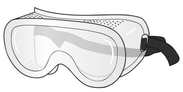
Explanation

When vinegar and baking soda combine, they form carbon dioxide gas as a product. This gas escapes the mixture causing the fizzing, bubbling reaction.

Have students follow the Scientific Procedure on page B - 49, working in groups of 1–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.



Reaction: Yes or No?

This handout is on p. B - 49.

SCIENTIFIC PROCEDURE

1. Add 5 spoonfuls of alcohol into the plastic bag.
2. Add 1 spoonful of baking soda into the same plastic bag.
3. Close the bag tightly and mix the baking soda and alcohol until the baking soda dissolves.
4. Dry the spoon with paper towel.
5. Add a pea-sized amount of turmeric powder. Close the bag and mix the bag contents for 30–60 seconds.
   - What do the contents of the bag look like?

Running Suggestions

- Remind students to completely seal their bags after adding the ingredients.

Choose higher quality resealable plastic bags with slightly thicker plastic, because upon excessive handling some of the turmeric might diffuse through the plastic onto students' fingers.

- If students double the ingredients, the bags may burst. Caution students against this (perhaps by emphasizing how the turmeric could stain their clothes).
- Watch students to see that they are careful when measuring the alcohol solution. One person should hold the spoon over the bag while the other person CAREFULLY squeezes alcohol onto the spoon.
- Discourage students from opening their bags after the reaction happens. The pressure of the gas can force the liquids out.

Ongoing Assessment

- Which chemical inside is changing color (baking soda, alcohol, turmeric, etc.)? Why do you think so? How could you find out? *Students can add any two of the ingredients to see which is responsible for the color change.*
- How can you tell there is a gas (or air) inside the bag? Can you see it?
- What new chemical or chemicals are being produced? How can you tell?
- Where do you think the heat is coming from?

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Caution students to be careful with the turmeric indicator since it can stain their fingers and clothes.
- Students can throw their bags away at the end of the experiment.

CAUTION: Isopropyl alcohol is flammable at 90% and 70% concentrations. At a concentration of 30–35%, its flammability is greatly reduced. Nevertheless, all open flames and sparks should ALWAYS be kept away from these solutions.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What did the chemicals look like before you mixed them in the bag?
The baking soda was a white powder. The turmeric was yellow and the alcohol solution was clear. The mixture of baking soda with turmeric is red.

How was the mixture different after you added the calcium chloride? What did you see, hear, and feel?
It turned yellow; it got hot/warm; the bag filled up with air; bubbles appeared; it got foamy, etc. Yellow color change, slight bubbling sound, heat in the baggie, etc.

What evidence of a chemical reaction do you notice?
The color changed. A new substance (a gas) was produced. The temperature changed.

How do you know that you have produced a gas? Can you see it?
Although the gas is invisible, students can infer its presence by observing the bubbles and the increase in volume of the bag.

How many color changes did you observe? What happened in each one?
There are two color changes—one when the yellow turmeric powder was added to the baking soda and turned red, and again when the calcium chloride was added and the solution turned yellow. In each case, the turmeric detected a base (baking soda) or an acid (carbon dioxide gas).

Where did the gas come from?
The baking soda produces the carbon dioxide gas in this experiment, although this is not necessarily obvious.

Caution students to not rush to this conclusion, however. There are many ingredients in the bag, and each of them could have produced the gas, in principle. Ask students how they could figure out where the gas came from—e.g., by eliminating ingredients to see if the reaction still occurs. (The mixture still bubbles without the turmeric, for instance.)

EXPLANATION

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

When atoms and molecules rearrange, they turn into new substances with different properties and different appearances. Students investigate and explore these changes in this activity.

BACKGROUND FOR ALL GRADES

In chemical reactions, substances interact and transform each other. When students combine all the chemicals in the bag, the bag warms up, the mixture changes color, and a new gas forms that inflates the bag. These changes show that a **chemical reaction** has occurred.

Signs of a Chemical Reaction
The following changes usually indicate a new substance has been formed:

- Appearance of a new gas, solid, or liquid
- Change in temperature
- Appearance of light
- Change in color
- Change in pH

What Happened in the Bag
The main reaction in the bag is between calcium chloride and baking soda. The calcium chloride causes the baking soda to break apart and produce carbon dioxide gas (CO_2). The other chemicals are incidental to this primary reaction.

In this reaction, students can identify the following signs of a chemical reaction:

- New gas: Since the CO_2 produced by baking soda and calcium chloride is a **gas**, it bubbles out of the liquid into the bag. As the many invisible gas molecules build up in the bag, they continuously bounce off the walls and therefore exert **pressure** that pushes out on the plastic, increasing the volume of the bag.
- Color change: The turmeric acts as a chemical **indicator** to the reaction of calcium chloride and baking soda. It starts red to indicate that baking soda is a **base**. As the reaction continues, it turns yellow to show an **acid** is being produced. For more on how turmeric works, see "The Role of Turmeric" below.

- Change in temperature: It takes energy to connect atoms together into molecules, and when those atoms are rearranged, as they are in chemical reactions, the energy changes. The difference in energy can be positive or negative. In this reaction, rearranging the atoms releases energy, which the students feel as heat.

> **Misconception Alert**: Students may incorrectly infer or claim that *any* temperature change shows a chemical reaction. This isn't true: some processes give off heat or light but don't make a new substance. For example, the glowing electric coil on a stove gives off both heat and light, as does the glowing wire in a light bulb. In both cases electricity is just heating metal hot enough to make it glow. The metal changes the electric energy into heat energy. Since no new substance is being created, there is no chemical reaction.

EXTRA BACKGROUND FOR GRADES 5–8

New Substances in the Bag

Although students are likely to notice only the carbon dioxide formed in this experiment, several new substances are actually created:

$2NaHCO_3$	+	$CaCl_2$	→	$2NaCl$	+	$CaCO_3$	+	CO_2 (gas)	+	H_2O
(baking soda)		(calcium chloride)		(table salt)		(limestone)		(carbon dioxide)		(water)

The table salt, limestone, and water formed in the reaction are very difficult to detect without more advanced chemical methods. Students might nevertheless improvise ways to detect these other chemicals. For instance, some students may notice the limestone as a white, chalky residue forming on the sides of the bag. Others might suggest letting the alcohol and water evaporate a bit to see if the limestone will **precipitate** or come out of solution (limestone is much less soluble in water than table salt).

Observant students may notice that not all of the baking soda or the calcium chloride has reacted. These two ingredients react in definite proportions to each other (as shown in the equation above, it takes twice as much baking soda as calcium chloride). Therefore it is likely that one will run out before the other.

Chemical Bonds and Energy

The substances in the bag are all made of **molecules**, i.e., collections of two or more **atoms** arranged in a certain way. For instance, baking soda molecules are each made of a sodium atom, a hydrogen atom, a carbon atom, and three oxygen atoms ($NaHCO_3$). When the atoms in these molecules interact chemically, they trade places and rearrange, producing new molecules (substances) with new characteristics. The baking soda, for instance, rearranges to produce CO_2 (a gas) and Na and OH.

When atoms and molecules react, they have to break the **chemical bonds** that hold them together and then form new bonds to make new substances. In this case, the formation of new bonds releases energy that the students feel as heat. In other cases, the formation of new bonds requires energy and the reaction will feel cold as heat is taken from students' hands.

The Role of Turmeric

Turmeric contains **curcumin**, a chemical that turns red with bases and yellow with acids in water. Baking soda is a base, so when students add turmeric, the curcumin in it turns red. The carbon dioxide produced in the reaction mixes with water to make an acid. So in the course of the reaction, the solution turns yellow.

Carbon dioxide produces acid (carbonic acid) in water through the following reaction:

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (dissolved)}$$

(carbonic acid)

Carbonic acid itself (H_2CO_3) is invisible in water, but when it reacts with the curcumin, it changes the shape of the curcumin molecule, causing that molecule to reflect light differently. This turns the curcumin yellow.

For information on pH and what it means with regard to acids and bases, see the activity ***Of Cabbages and Kings.***

EXTENSIONS

Extension A: Turmeric Indicator

Students add turmeric indicator to various household items to determine if they are acids or bases.

Extra Supplies

- two extra cups with ¼ cup each baking soda and calcium chloride
- extra ¼ to ½ cup turmeric indicator (dissolve ½ teaspoon turmeric per cup of 30% isopropyl alcohol to make an acid base indicator)

Choose one or all of the following:

- vinegar in a plastic cup (¼ cup per group)
- lemon or lime juice in a plastic cup (¼ cup per group)
- ammonia in a plastic cup (¼ cup per group)
- 7UP, Sprite, or another clear soda in a plastic cup (¼ cup per group)
- saltwater in a plastic cup (¼ cup per group)

Extra Instructions

Add turmeric indicator to each of the items. If the turmeric turns red, the item is a base. If the turmeric stays yellow, the item is an acid.

Extension B: Deicer Product Testing
Students test the effectiveness of different products to melt ice. (Many such products use calcium chloride, which heats up on contact with water.)

Extra Instructions

- Follow the link in the Resources section of this activity to the Journal of Chemical Education's Web site to the Lesson "Meltdown Showdown! Which Deicer Works Best?"
- There is some advanced preparation required (making ice blocks ahead of time). Alternatively, if you live somewhere where ice is common in the winter, do the same activity outside.

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES — **Research the History of Chemical Reactions**
Have students research and report on early, famous chemical reactions or chemical concoctions, such as Greek fire (used by Greek sailors to burn enemy ships) or fireworks (developed by the Chinese). Students should identify why each instance is a chemical reaction.

MATHEMATICS — **Graph Temperature Changes**
Have students measure the temperature change of the reaction with small steel thermometers (they can be placed directly in the resealable bags and read through the clear plastic). If students would like to vary the amounts of baking soda and calcium chloride, they can produce and compare different temperature graphs.

RESOURCES

Web – http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The Journal of Chemical Education publishes online lesson plans for high school students on multiple topics. Under the topic, Consumer Chemistry, the lesson "Meltdown Showdown! Which Deicer Works Best?" investigates the effectiveness of different brands of deicers.

Web – http://www.chem4kids.com/files/react_intro.html
A brief overview of chemical reactions with colorful pictures that show atoms from different molecules combining and rearranging to form new substances.

Color Changing Paper
Available at most Kinko's stores, this goldenrod paper is bright gold but will change to bright red when exposed to base. It contains the same dye, curcumin, that makes the turmeric change color in this experiment. The brand is Wausau Papers, Astrobrights, Galaxy Gold.

VOCABULARY

acid: a substance with an excess of available hydrogen ions; often sour in taste

atom: a very, very small particle that makes up all matter

base: a substance that takes up hydrogen ions; often bitter in taste

chemical bond: a connection that holds two atoms together

chemical reaction: when two substances are mixed together to create a new substance; often characterized by fizzing, color change, change in temperature, or creation of light

curcumin: the active ingredient in turmeric that changes color in acids and bases

gas: state of matter where molecules are spread far apart and interact only by random collisions; this state will expand to fill a container of any size

indicator: A chemical that changes color to show the presence or amount of a certain chemical

molecule: a group of at least two atoms held together in a definite arrangement

pressure: continuous force applied by touching; force on a surface created by collisions of gas molecules

precipitate to come out of a liquid solution as a solid

Reaction: Yes or No?

SCIENTIFIC PROCEDURE

1. Add 5 spoonfuls of alcohol into the plastic bag.

2. Add 1 spoonful of baking soda into the same plastic bag.

3. Close the bag tightly and mix the baking soda and alcohol until the baking soda dissolves.

4. Dry the spoon with paper towel.

5. Add a pea-sized amount of turmeric powder. Close the bag and mix the bag contents for 30–60 seconds.
   - What do the contents of the bag look like?

6. Put 1 heaping spoonful of calcium chloride into the same plastic bag. Close the bag and mix the bag contents for 30–60 seconds.
   - Do you notice any changes occurring?

   - What do you feel, hear, and see?
   - What evidence is there of a chemical reaction?

7. Clean up your area.
   - Follow your teacher's directions

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Reaction: Yes or No?

Recommended group size: 1–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
sealing plastic bag, (e.g., Ziploc™) pint or sandwich size	1 per group		
plastic spoons	3 per group		
turmeric	1 teaspoon per group		
baking soda	¼ cup per group		
calcium chloride	¼ cup per group		
isopropyl alcohol, 70% (rubbing alcohol) or 90%	< ¼ cup per group		
plastic cups, 8 oz.	3 per group		
Extension A			
extra plastic cups	1 per extra ingredient per group		
vinegar	¼ cup per group		
lemon or lime juice	¼ cup per group		
ammonia	¼ cup per group		
clear soda (7UP, Sprite)	¼ cup per group		
salt water	¼ cup per group		
Extension B			
Follow the link in the Resources section to the Journal of Chemical Education's Web site to the Lesson "Meltdown Showdown! Which Deicer Works Best?"			
Teacher Demonstration			
Acid Base Indicators			
clear plastic cups, 8 oz. or larger	2 for demonstration		
30% or 35% alcohol solution from the activity	½ cup in each plastic cup		
turmeric indicator			
vinegar	1 tablespoon		
baking soda	1 teaspoon		
Gas Production			
baking soda	1 teaspoon		
vinegar	¼ cup		
plastic cup, 12 oz.			

Píntame de Colores

PROCEDIMIENTO CIENTÍFICO

1. Agrega dos cucharadas de la solución de cloro en cada uno de los tres vasos.

2. Agrega 4 gotas de colorante **amarillo** en el primer vaso. Revuelve la solución. Obsérvalo por 30 segundos.
   - *¿Qué sucede con el colorante amarillo?*

3. En el próximo paso agregarás colorante **azul** al segundo vaso. Pero antes de hacerlo:
   - **Predice:** *¿Qué crees que sucederá cuando agregues el colorante azul?*

4. Agrega 4 gotas de colorante **azul** en el segundo vaso. Revuelve la solución. Obsérvalo por 30 segundos.
   - *¿Qué sucede con el colorante azul?*

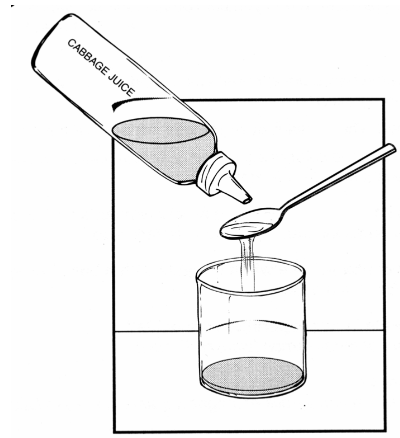
5. En el próximo paso agregarás colorante **verde** al tercer vaso. Pero antes de hacerlo:
   - **Predice:** *¿Qué crees que sucederá cuando agregues el colorante verde?*
   - **Explica:** *¿Cuáles son tus razones para hacer esta hipótesis?*

6. Agrega 4 gotas de colorante **verde** en el tercer vaso. Revuelve la solución. Obsérvalo por 30 segundos.
   - *¿Qué sucede con el colorante verde?*
   - *¿Confirma este experimento tu hipótesis? ¿Por qué sí o por qué no?*

7. Limpia tu área de trabajo.
   Sigue las instrucciones de tu maestro(a).

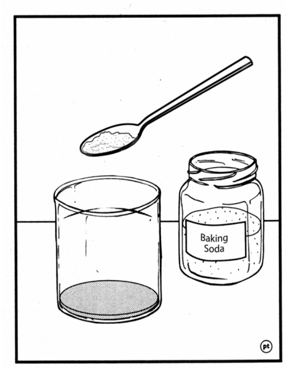
¿De qué Col-Ores?

PROCEDIMIENTO CIENTÍFICO



1. Agrega dos cucharadas de jugo de repollo en un vaso.
   - ¿Cómo se ve?

2. Agrega una cucharada de bicarbonato de sodio en el vaso.
   - ¿Qué sucedió?



   - ¿Cómo se ve ahora?

3. Prueba la reacción de otros polvos y líquidos con el jugo de repollo y escribe tus observaciones.

4. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

¿De qué Col-Ores?

TABLA DE DATOS

Escribe tus observaciones en la tabla de abajo.

Nombre del químico agregado	Color del jugo de repollo (antes)	Color del jugo de repollo (después)	Conclusión: ¿Ácido o Base?

Reacción: ¿Sí o No?

PROCEDIMIENTO CIENTÍFICO

1. Agrega 5 cucharadas de alcohol en la bolsa de plástico.

2. Agrega 1 cucharada de bicarbonato de sodio en la misma bolsa.

3. Cierra bien la bolsa y sacúdela hasta que se disuelva el bicarbonato.

4. Seca la cuchara con una toalla de papel.

5. Agrega una pequeña cantidad (como del tamaño de un chícharo) de polvo de cúrcuma. Cierra la bolsa y mezcla el contenido de 30–60 segundos.
   - *¿Cómo se ve el contenido de la bolsa?*

6. Coloca una cucharada de cloruro de calcio en la misma bolsa plástica. Cierra la bolsa y mezcla el contenido de 30 a 60 segundos.
   - *¿Está ocurriendo algún cambio?*
   - *¿Qué sientes, escuchas y ves?*
   - *¿Qué evidencias hay de una reacción química?*

7. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Concepts

In a chemical reaction, there is a change in the way atoms and molecules combine. Signs of a chemical reaction include: color or temperature change or the production of light, electricity, or a new material.

Words to know

acid - a chemical or compound that has an excess of hydrogen ions; often sour in taste.
atom - a very, very small particle that makes up all matter.
base - a chemical or compound that takes up hydrogen ions; often bitter in taste.
concentration - the ratio of the amount of a chemical in a solution to the volume of the solution.
chemical bond - a connection that holds two atoms together.
chemical reaction - an interaction of atoms or molecules to form new elements or molecules.
electron - a negatively charged part of an atom.
endothermic reaction - a chemical reaction that absorbs heat and that may feel cold.
equilibrium - a point reached during a chemical reaction when no further changes occur.
exothermic reaction - a chemical reaction that gives off heat and that may feel hot.
ion - an atom or molecule with an electrical charge.
indicator - a chemical that changes color with changes in pH.
matter - anything that has mass and occupies space.
mixture - two or more materials that are mixed together but not chemically bonded.
molecule - a group of at least two atoms held together in a definite arrangement.
pH - a scale that measures relative acidity and basicity.
solution - a completely uniform mixture.

Find these Words to Know in the word search below.

ACID	INDICATOR
ATOM	ION
BASE	LIGHT
BUBBLES	MATTER
CHEMICAL BOND	MIXTURE
CONCENTRATION	MOLECULE
ELECTRON	OMSI
ENDOTHERMIC	REACTION
EQUILIBRIUM	SOLUTION
EXOTHERMIC	TEMPERATURE

I	E	M	E	E	L	T	W	M	K	G	W	E	C	O
S	L	B	I	S	L	O	Q	A	U	O	V	U	I	E
M	E	U	T	X	A	U	J	T	A	C	I	D	M	X
O	C	B	G	H	T	B	C	T	X	H	U	F	R	O
I	T	B	N	S	G	U	Y	E	M	X	K	A	E	T
Q	R	L	A	E	J	I	R	R	L	S	T	I	H	H
F	O	E	A	S	L	D	L	E	F	O	O	X	T	E
W	N	S	K	G	E	G	A	A	M	M	M	N	O	R
C	O	N	C	E	N	T	R	A	T	I	O	N	D	M
M	F	E	Q	U	I	L	I	B	R	I	U	M	N	I
I	N	D	I	C	A	T	O	R	T	C	M	K	E	C
S	O	L	U	T	I	O	N	C	B	C	A	E	D	M
B	O	N	D	N	O	B	L	A	C	I	M	E	H	C
H	O	R	N	G	C	E	I	O	N	I	M	E	Q	C
E	R	U	T	A	R	E	P	M	E	T	V	H	K	G

OREGON MUSEUM OF SCIENCE AND INDUSTRY

CheM LaB

Take-Home Activities

Chemical Reactions

Cloudy Globs

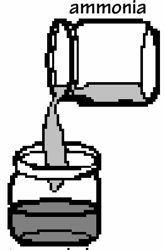
Can you make a white gel from two clear liquids?

Materials:

two small jars or glasses (about 4-oz.)
warm water
alum (in the spice aisle at grocery stores)
1/2 teaspoon measure
1 teaspoon measure
ammonia

To do and notice:

1. Fill one jar half full with warm water.
2. Add ½ teaspoon alum. Stir or shake to mix the water and alum completely.
3. To the other jar, add 2 teaspoons ammonia.
   - **What do the solutions look like in each jar?**
   - **Are the solutions clear or cloudy?**
4. Pour the ammonia into the jar with water and alum.
   - **What happens?**
5. Allow the jar with the new mixture to sit for a while.
   - **What do you see at the bottom of the jar?**



A closer look:

Alum dissolves in water to make a clear solution. Ammonia (NH_3) reacts with water to make a clear solution of ammonium hydroxide (NH_4OH), or household ammonia. When you mix these two clear solutions together, they react to form a new compound.

Alum contains aluminum. When alum reacts with ammonia, aluminum hydroxide ($Al(OH)_3$) is formed as a product of the reaction. Aluminum hydroxide does not dissolve in water and forms cloudy white globs. As the globs settle, they form a solid gel at the bottom of the jar.

Glow Fast, Glow Slow

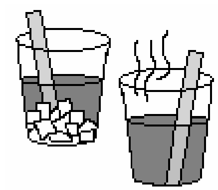
Alter the rate of a reaction!

Materials:

two clear glasses or jars
water
ice
two identical "lightsticks"
a dark room or area

To do and notice:

1. Run hot water from the faucet until it is quite hot. (**Caution**: be careful not to burn yourself.) Fill one glass with the hot water.
2. Fill the other glass with ice and water.
3. Activate both lightsticks by bending them until they snap and then shaking them.
   - **What do you observe?**
4. Put one lightstick in each jar.
5. Turn out the lights or take the jars to a dark room or closet.
   - **Which lightstick is glowing brighter?**
   - **Which lightstick glows longer?**



A closer look:

Energy transfer is part of all chemical reactions. The reaction in lightsticks releases energy in the form of light. This process is called "chemiluminescence."

A temperature change can cause a chemical reaction to go faster or slower. Heat speeds the rate of the chemical reaction, so the lightstick in hot water is brighter. Cold slows the rate of the reaction, so the cold lightstick's supply of chemicals lasts longer. (Depending on the brand you use, they may last 20 minutes to several hours.)

Gas Production

Blow up a balloon!

Materials:

baking soda	tablespoon
small cup	vinegar
funnel	
one plastic bottle (1 liter or 20 ounces)	
one large balloon (8" or 9" size)	

To do and notice:

1. Measure 2 tablespoons of baking soda. Pour the baking soda into the plastic bottle.
   - **What does the baking soda look like?**

2. Rinse and dry the tablespoon. Measure 3 tablespoons vinegar. Pour the vinegar into the small cup.
   - **What does the vinegar look like?**
3. Using the funnel, pour the vinegar into the balloon.

4. Attach the lip of the balloon onto the mouth of the bottle. Be careful not to spill the vinegar.
5. After the balloon is attached, lift the balloon to dump the vinegar into the bottle.
   - **What do you hear?**
   - **What do you see?**
   - **What is happening to the balloon?**

A closer look:

When you mix vinegar and baking soda, their molecules interact and make new substances.

Baking soda, also called sodium bicarbonate, has the formula $NaHCO_3$. Vinegar, also called acetic acid, has the formula CH_3COOH. When they recombine they make sodium acetate ($NaCH_3COO$), water (H_2O), and carbon dioxide (CO_2).

Carbon dioxide is the gas that creates bubbles inside the bottle and inflates the balloon.

Bend a Carrot

Learning Objectives: *Students understand the process of osmosis, the net movement of water through a barrier.*

GRADE LEVEL

5–8

SCIENCE TOPICS

Atoms and Molecules
Techniques
Organic & Biochemistry

PROCESS SKILLS

Comparing/Contrasting
Describing/Defining
Controlling Variables
Explaining

GROUP SIZE

1–2

SNEAK PEAK inside …

ACTIVITY

Students observe changes in carrots exposed to salt.

STUDENT SUPPLIES

see next page for more supplies

carrots
sealing plastic bags (e.g., Ziploc™)
salt
plastic cups and spoons, etc.…

ADVANCE PREPARATION

see next page for more details

Fill student cups with salt
Put out carrots, etc.…

OPTIONAL EXTRAS

DEMONSTRATION

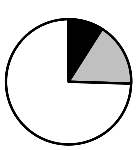
Super-Absorbent Diapers (p. C - 3)
Expanding Crocodiles (p. C - 5)

EXTENSIONS

Measuring Water Loss (p. C - 10)
Hypertonic and Hypotonic Solutions (p. C - 11)
Inquiry Opportunity—Test Variables (p. C - 12)

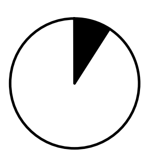
TIME REQUIRED

Advance Preparation



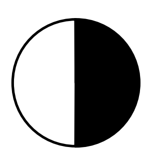
5–15 minutes

Set Up



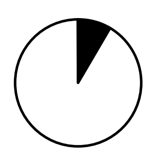
5 minutes

Activity



30 minutes

Clean Up



5 minutes

SUPPLIES

Item	Amount Needed
carrots (purchase baby carrots or cut large carrots to 3" sticks)	4 per group
sealing plastic bags (e.g., Ziploc™)	2 per group
permanent markers (e.g., Sharpie™)	1 per group
salt	¼ cup per group
small plastic cups, 8 oz.	1 per group
plastic spoons	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Carrots:

- ❑ Purchase peeled or unpeeled baby carrots.

OR

- ❑ Purchase large carrots and cut into 3" sticks.

Salt:

- ❑ Fill plastic cups with 2 spoonfuls of salt.
- ❑ Label the plastic cups "salt."

SETUP

For each group

- ❑ 4 carrots (or carrot pieces)
- ❑ 2 sealing plastic bags
- ❑ 1 permanent marker
- ❑ 2 spoonfuls salt in a plastic cup
- ❑ 1 plastic spoon

At a central location (or with the teacher)

- ❑ sponges and towels for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided primarily for the teacher's benefit.

Choose questions that are appropriate for your classroom.

In this activity, students will add salt to raw carrots and observe the water come out of the carrots.

Have you ever seen wilted plants? What makes plants wilt? What makes plants stand up straight?
A lack of water will make a plant wilt. Giving a plant water will help it stand up straight.

How does the water from the pot get into the plant?
Water moves from the soil into the roots. The water can then move through the plant.

If water moves into plants, can it move out of them? How does water usually leave a plant?
Students may say that water goes back into the soil, that it disappears, or that it evaporates as from a pan left on the countertop.

In this activity, students will have the opportunity to see how the water in plants and plant roots (carrots) responds to salt concentrations. They will see osmosis at work.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

TEACHER DEMONSTRATION

Because the osmosis activity takes some time, you may wish to have the students start the activity first. Then do a demonstration while you are waiting for the osmosis to proceed.

Super Absorbent Diapers
Show how much water a diaper can absorb.

Supplies
- overnight diaper
- scissors
- 1 gallon sealable plastic bag (e.g., Ziploc™)
- 2-L bottle filled with water
- 2 tablespoons of salt

Demonstration

- Holding the diaper in the bag, cut open the diaper. Inside the diaper, find the powder-filled absorbent pad. Leave the pad and powder in the bag and remove the rest of the diaper. (Keeping the pad and powder inside the bag keeps the powder from spreading.)
- Add water to the bag a little at a time, sealing and squishing the bag between each addition. Pass the bag around the classroom for students to squish as well. One large diaper will hold approximately
  2 liters of water in a spongy gel.
- Add 2 tablespoons of salt to the gel in the bag. Massage this thoroughly into the gel. All the water will come out of the gel and can be seen in the bag.

CAUTION: Although the powder and gel are non-toxic, it is best not to touch either. The powder or gel can be washed off of skin with soap and water.

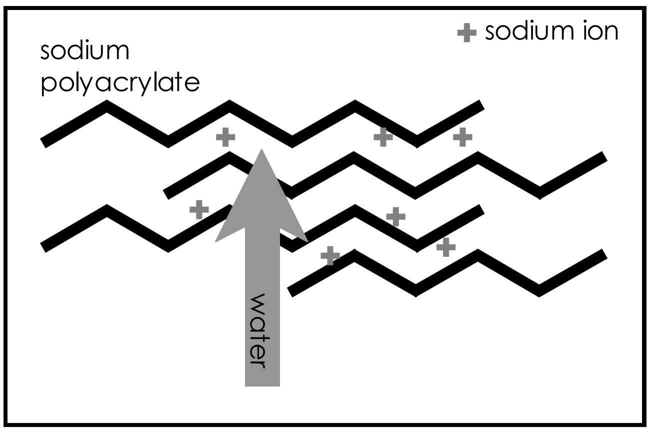


Figure 1 When sodium polyacrylate is surrounded by plain water, the concentration of sodium is less outside the net. In this case, water rushes into the network.

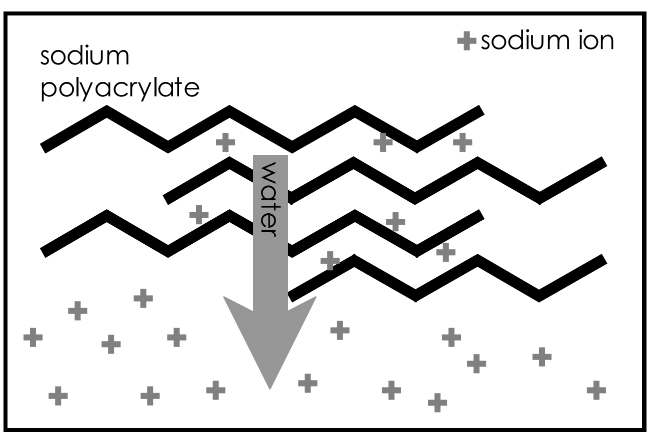


Figure 2. When sodium polyacrylate is surrounded by salt, the concentration of sodium is greater outside the net. In this case, water rushes out of the network.

Explanation

The powder in the diaper is a chemical called sodium polyacrylate. Sodium polyacrylate is amazingly absorbent. It can absorb 500 to 800 times its weight in pure water.

Sodium polyacrylate is made of long molecular chains connected in a large network (see Figure 1). This network is similar to a cell membrane in that it allows water to pass through. Trapped inside this network are charged particles of sodium called **ions**. When water is first added to the powder, the concentration of sodium ions inside the network is higher, so water rushes into the gel. The sodium polyacrylate network stays intact but swells to form a soft gel.

When salt is added, the water rushes out again. Table salt is a chemical called sodium chloride. Salt contains sodium ions, like the polyacrylate. When you add salt to the gel, the increased sodium ion concentration on the outside pulls the water out (see Figure 2). Diapers normally do not absorb as much urine as water because urine contains dissolved salts.

Expanding Crocodile

Watch a toy grow as it absorbs water over several days.

Supplies

- 3 toy expanding crocodiles (available at toy stores, the OMSI Science Store, 503-797-4626, or Flinn Scientific, www.flinnsci.com)
- 2-L bottle filled with water
- 2-L bottle filled with salt water (3 tablespoon of salt to 2 liters of water)

Demonstration

- Put one toy crocodile into the bottle filled with water.
- Put one toy crocodile into the bottle filled with saltwater.
- Save the third crocodile for comparison.
- Allow the bottles to sit for at least 48 hours.
- Compare the sizes of the crocodiles in the bottles to the dry crocodile.

Explanation

The toy crocodiles are made from two polymers—starch and polyacrylonitrile—and glycerin to form a plastic gel that can be molded into a toy. These polymers work in a similar way as the sodium polyacrylate in disposable diapers. The plastic gel in these toys can absorb up to 400 times its mass in water.

The crocodile in the salt water will not grow as much as the one in plain water. This is because there are sodium ions in the water outside the crocodile as well as in the crocodile.

If you remove the crocodiles from the water, they will dry and return to their original size.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page C - 14, working in groups of 1–2. Below are suggestions to help the teacher facilitate the activity.

NOTES

This handout is on p. C - 14.

Bend a Carrot

SCIENTIFIC PROCEDURE

1. Label your bags.
   - Label one bag "Salt" and the other bag "No Salt."
2. In the bag labeled "Salt" add 1 spoonful of salt.
3. Add two carrots to each bag.
   - Shake the bag to mix the carrots and the salt.
   - Wait about 30 minutes.
4. Observe your carrots.
   - How have the carrots changed?

Running Suggestions

- Because the osmosis activity takes 15–30 minutes, you may wish to start the activity with students first. Then do a demonstration while you are waiting for the osmosis to proceed.
- You may choose to have students keep their bags of carrots in the classroom overnight. After 24 hours, even more water will move out of the carrots.

Ongoing Assessment

- Circulate around the room and ask students for their observations. Encourage them to touch the carrots through the bags.
- How are the carrots the same in each bag? How are they different?
- Is there new material appearing? Where is it coming from?

Misconception alert: When students see the water come out of the carrots in this experiment, they may think the salt is melting, since the source of the water is not clear, and since the amount of salt seems to decrease as it dissolves in the water from the carrots.

Safety and Disposal Information

- All materials may be thrown away.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

How do the carrots look after being in the bags? How are they the same? How are they different?
The carrots from the bag with salt bend easily. There is a lot of water in the bag with the salt. The carrots in the bag without salt look the same as when they started.

What would happen if we left them in for a longer time?
The carrots would lose more water; other students might believe they have already lost all their water.

How is this similar to what happens in plant roots?
When the soil is dry, water moves out of the roots into the soil. Alternatively, when the soil is salty and wet, water also moves out of the plant roots into the soil.

Does this only happen with salt or would it happen with other chemicals as well?
Yes, it happens with all particles. Soil has no salt, but when the soil around plant roots is dry, the water will leave the roots. Maybe we should do the same experiment with something else to test.

Students should understand that through osmosis, the water moved from the carrots to the salt. Salt contains sodium ions in higher concentration than that in the carrot, so the water moves out of the carrot.

EXPLANATION

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

This experiment investigates the movement of water into and out of cells. The movement of water in and out of cells depends on the amounts of dissolved chemicals (like sugar or salt) inside and outside of cells. Plants rely on the water in their cells to help them stand up straight—they wilt when they don't have enough water in their cells.

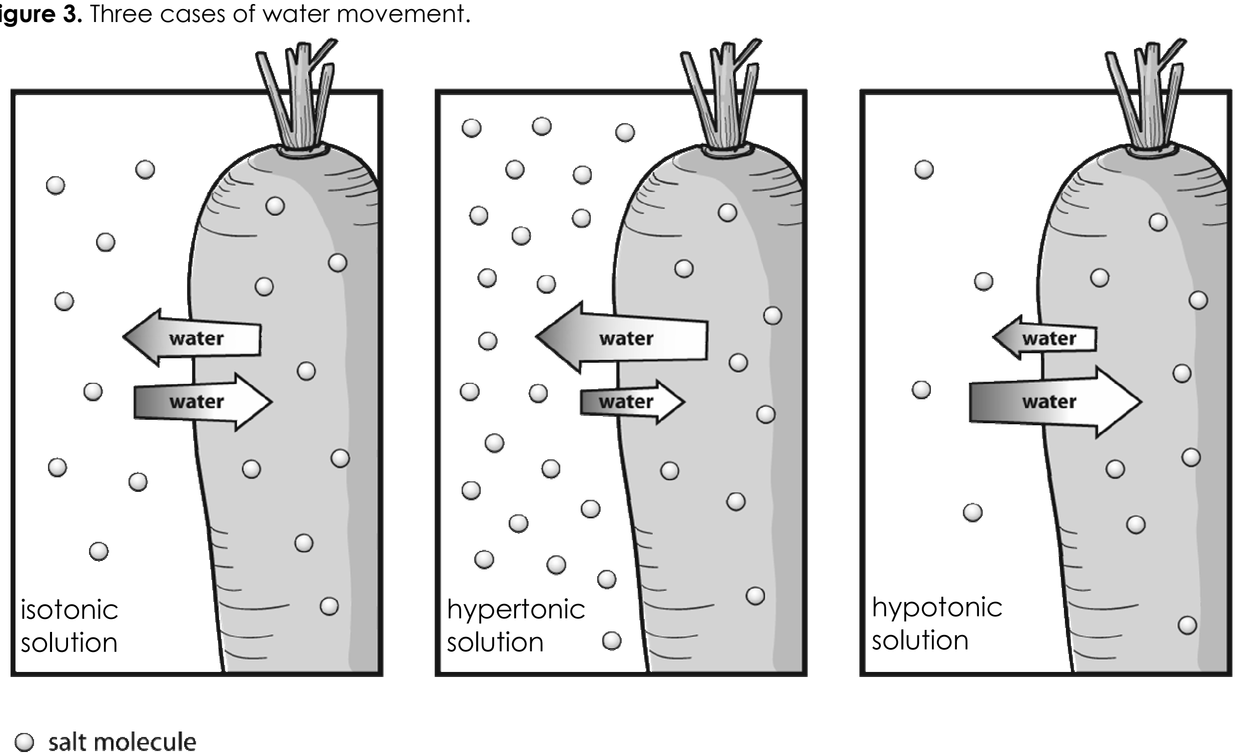
Movement of Water

All cells are surrounded by a barrier called a **cell membrane**. The cell membrane controls the movement of most chemicals into and out of the cell. One exception to this is water. Cell membranes allow water to move into and out of the cell. When water moves across a cell membrane in a particular direction (see Figure 3), it is called **osmosis**.

The direction water moves across the membrane depends on the **concentration** of particles (e.g., the amount of dissolved salt, sugars, starch, etc.) inside and outside the cell.

ISOTONIC: When the concentration of particles inside and outside the cells is the same, the solutions are **isotonic** (*iso-* means *same* and *–tonic* means *solution*). In this case, water moves equally into the cell and out of the cell.

Figure 3. Three cases of water movement.



HYPERTONIC: When the concentration of particles outside the cell is greater than the concentration inside, the outside is called **hypertonic** (*hyper-* means *more*). In this case, more water will move out of the cell. As water leaves the cell, the cell starts to shrivel and shrink.

HYPOTONIC: When the concentration of particles outside the cell is less than the concentration inside, the outside is called **hypotonic** (*hypo-* means *less*). In this case, more water will move into the cell than out.

In other words, osmosis is the spontaneous, net movement of water to an area of higher concentration of particles.

Plants and Osmosis

When plant cells are placed in solutions of low concentration, they have a strong advantage over animal cells. Living cells are full of sugars, salts, and other chemicals. This means there is usually a higher concentration of particles inside the cell, and water will move into cells.

So much water can move into animal cells in this way that they might eventually **lyse** (break open). This is similar to inflating a balloon until it pops. Plant cells have an advantage because they have an extra barrier around the cell membrane called a **cell wall** (see Figure 4). The rigid cell wall provides extra structural support, helping plant cells to not break open as easily.

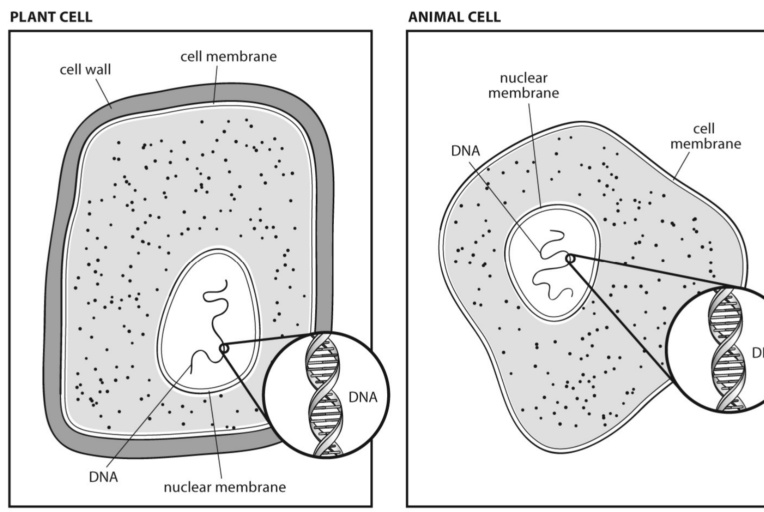


Figure 4. Structure of plant cells and animal cells. The rigid cell walls in plant cells keep the cell from bursting when water enters.

When a plant's cells are filled with water (or **turgid**) they become physically strong enough to hold up the weight of the plant.

When the soil around the roots of a plant is dry, the concentration of particles outside the plant is now greater. Plant cells lose water, the cells shrivel, shrink, and the plant wilts.

Water Regulation is the Key to Cell Function

Many forms of life, including fish, use a special technique (called **osmoregulation**) to control the flow of water into and out of their cells. For example, saltwater fish must keep the water in their cells from flowing out into the salty water around them, because that water has a higher concentration of dissolved particles. On the other hand, fish swimming in freshwater need to prevent freshwater from flowing into their bodies, because their cells have a higher concentration of particles.

Misconception Alert: Even though all the examples in this explanation refer to the concentration of salt solutions, osmosis is not limited to salt. Starch, sugar, and other minerals also dissolve to increase concentrations and cause water to move into and out of cells.

EXTENSIONS

Extension A: Measure Water Loss
Measure the mass of the carrots before and after the activity.

Extra Supplies
- balance or scale that can measure in grams or fractions of ounces

Extra Instructions
- Mark or arrange the carrots in some way to tell them apart.
- Record the mass of each carrot before the activity.
- After the activity, rinse and dry all carrots.
- Record the mass of each carrot after the activity.

Explanation
The change in mass of the carrots is:

mass of water lost = initial mass of dry carrot – final mass of dry carrot

Students can assume the change in mass is due to the mass of water lost, either through evaporation or osmosis. Additionally, since the density of water is about 1 gram per
1 milliliter, students can find the **volume** of water lost by the relation

1 g water = 1 milliliter water

Extension B: Hypertonic vs. Hypotonic (Grades 7–8)
Place carrots into different kinds of salt solution to see what happens to them. Students should predict what direction osmosis will occur and then test their predictions.

Extra Supplies
- plastic cups, 6 oz. or larger
- salt
- measuring spoons, ½ teaspoon and 1teaspoon
- pop-top squeeze bottles (e.g., water or sports drink) filled with water

Extra Instructions
- There is an additional Scientific Procedure sheet on p. C - 15.
- Label the cups #1, #2, #3, and #4, or with the salt amounts. (An example range is shown; other ranges of salt concentration will also work.)
    - #1: none
    - #2: ½ teaspoon
    - #3: 1 teaspoon
    - #4: 2 teaspoons
- Add the above amounts of salt to the corresponding cup.
- Add water to each of the 4 plastic cups for the same total volume.
- Leave carrots in the solutions overnight.

Explanation

The water inside carrots contains all the sugars, salts, proteins, and DNA of the carrots. Pure water is hypotonic to (less concentrated than) this solution. When carrots are placed in pure water, the water moves into the carrot through osmosis, causing them to swell and become stiff; some carrots may crack open due to the pressure.

Each salty water solution used in this extension may be more or less concentrated than the solution inside carrots. If the solution is more salty (i.e., hypertonic) than the carrots, the carrots will become squishy and may shrink, just as in the regular activity.

Extension C: Inquiry Opportunity—Test Variables
There are many possible variables to change in this experiment.

Additional materials
- different vegetables (e.g., celery, potatoes, cucumbers)
- different solids (e.g., sugar, baking soda, Epsom salt, detergent, calcium chloride)
- different liquids (e.g., vinegar, oil, corn syrup)
- pop-top squeeze bottles (e.g., water or sports drink) to contain different liquids

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

Explanation

Younger students can design a simple experiment using the standard directions. Older students should use techniques learned in Extensions A and B to design a scientific investigation. Students should predict the direction of osmosis, test, and explain their results.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS

Graphing Change
After doing Extension A, students can make a bar graph comparing the change in mass of carrots mixed with salt to those without.

SOCIAL STUDIES

Research Report
Carrots have a long history. From their humble beginnings as a white or purple root in Afghanistan, to their current value as a modern source of vitamins and antioxidants, there is much to be learned about this amazing vegetable. A good start is the link to the Carrot Museum listed in Resources.

RESOURCES

Web – http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The Journal of Chemical Education publishes online lesson plans for high school students on multiple topics. Under the topic, Biochemistry, the lesson by Bertoluzzo, et al. investigates osmosis. The first half of the investigation requires advanced technique and chemicals. The second investigation is appropriate for younger students. Students observe onionskin under a microscope as water and saltwater solutions are added.

Web – http://www.tvdsb.on.ca/westmin/science/sbi3a1/cells/osmosis.htm
Good graphics about the process of osmosis in hypertonic, hypotonic, and isotonic solutions.

Web – http://www.carrotmuseum.co.uk
An extensive site about carrots, their history, their cultivation, nutritional value, and literary references. Contains many links to external sites as well as detailed information on the site.

VOCABULARY

cell membrane: a thin barrier that surrounds the contents of plant and animal cells, controlling the passage of water and other chemicals both into and out of the cell

cell wall: the rigid outermost cell layer found in all plants and some algae, bacteria, and fungi; absent from all animal cells

concentration: the ratio of the amount of a chemical in a solution to the volume of the solution

hypertonic: having a higher concentration of particles in solution; *hyper* means *more*

hypotonic: having a lower concentration of particles in solution; *hypo* means *less*

ions: an electrically charged atom or group of atoms

isotonic: having the same concentration of particles in solution; *iso* means *same*

lyse: to break open or split

osmoregulation: the process whereby living cells control the flow of water across their cell membranes

osmosis: the movement of water molecules across a barrier; water spontaneously moves from a region of low particle concentration to a region of high particle concentration

turgid: so full of water as to be stiff and rigid

Bend a Carrot

SCIENTIFIC PROCEDURE

1. Label your bags.
   - Label one bag "Salt" and the other bag "No Salt."

2. In the bag labeled "Salt" add 1 spoonful of salt.

3. Add two carrots to each bag.
   - Shake the bag to mix the carrots and the salt.
   - Wait about 30 minutes.

4. Observe your carrots.
   - How have the carrots changed?
   - How are the carrots different in each bag?
   - How do the carrots feel when you bend them?

5. Clean up your area.
   - Follow your teacher's directions.

Bend a Carrot

SCIENTIFIC PROCEDURE—Extension B

1. Label your cups.
   - Write your name(s) on all cups.
   - Label the cups: "water," "½ teaspoon salt," "1 teaspoon salt," and "2 teaspoons salt."

2. Add salt and water to your cups.
   - Carefully add the correct amount of salt to each labeled cup

3. Add water to the cups so that each has the same total amount of liquid. The amount is not important, except that it be the same.
   - Stir the solutions in each cup.

4. Add two carrots to each cup. Leave the cups overnight.

5. The next day, observe your carrots.
   - Which solutions were hypotonic (less salt) compared to the carrot?
   - Explain how you know.

   - Which solutions were hypertonic (more salt) compared to the carrot?
   - Explain how you know.

   - Which solution was isotonic (equal salt) compared to the carrot?
   - Explain how you know.

6. Clean up your area.
   - Follow your teacher's directions.

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Bend a Carrot

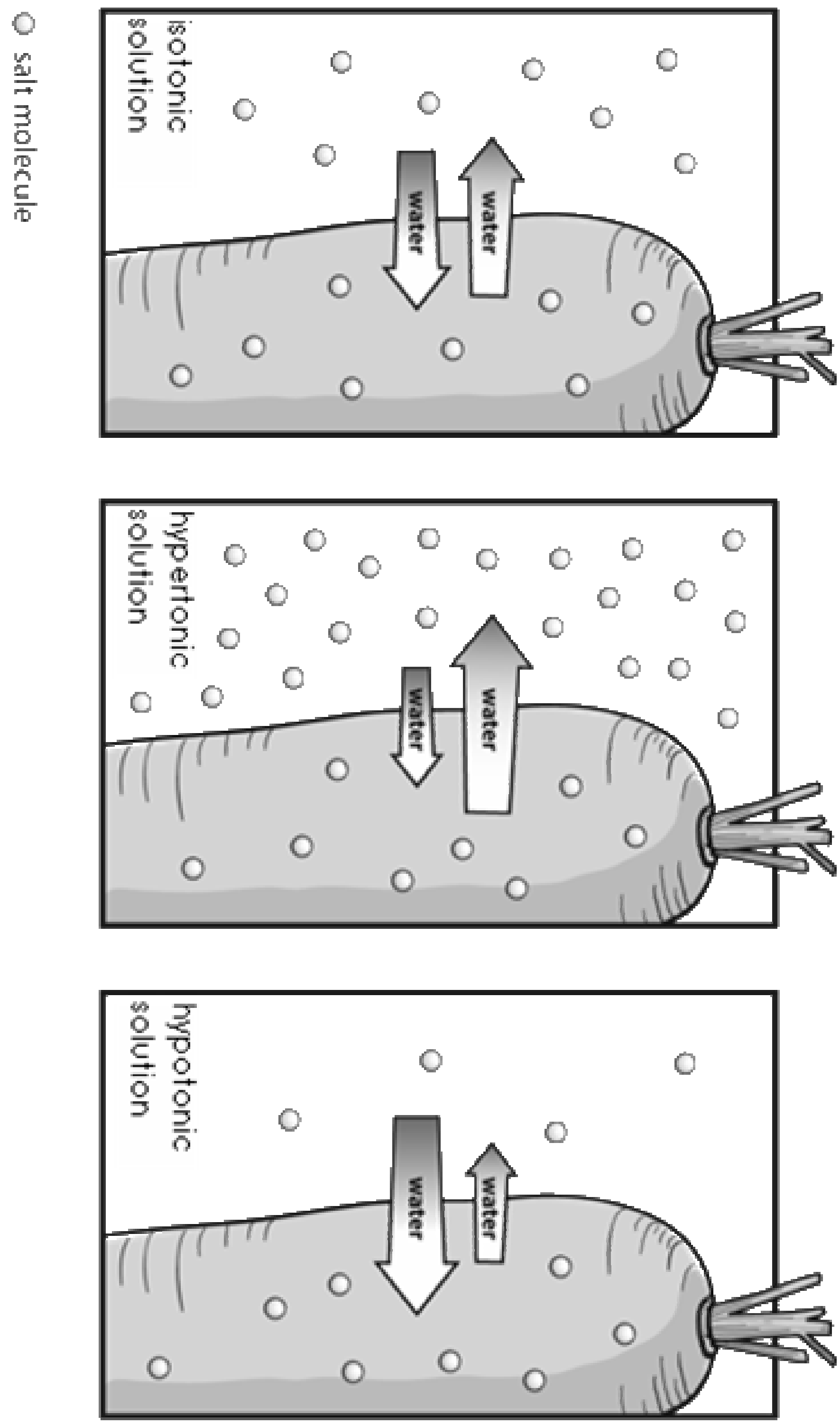
Recommended group size: 1–2

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
carrots (baby carrots or cut large carrots to 3" sticks)	4 per group		
sealable plastic bags (e.g., Ziploc™)	2 per group		
permanent markers (e.g., Sharpie™)	1 per group		
salt	¼ cup per group		
small plastic cups, any size	1 per group		
small spoons (e.g., teaspoons)	1 per group		
masking tape	1 roll per class		
Extension A			
balance or scale	1 per group or a few for class to share		
Extension B			
plastic cups, 6 oz. or larger	4 per group		
additional salt	¼ cup per group		
measuring spoons, ½ teaspoon and 1 teaspoon	1 each per group		
pop-top squeeze bottles (e.g., water or sports drink) filled with water	1 per group		
Extension C			
different vegetables—for example, celery, potatoes, cucumbers cut to 3" sticks	4 pieces of each vegetable per group		
different solids—for example, salt, sugar, baking soda, Epsom salt, detergent	¼ cup per group		
different liquids—for example, vinegar, oil, ammonia, corn syrup	1 cup per group		
pop-top squeeze bottles (e.g., water or sports drink) to contain different liquids	2–3 for each liquid		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Teacher Demonstration			
Super Absorbent Diaper			
overnight diaper	1 per class		
scissors	1 pair for class		
1 gallon sealable plastic bag (e.g., Ziploc)	1 for class		
2-L bottle filled with water	1 for class		
salt	2 tablespoons		
Expanding Crocodile			
toy expanding crocodiles (available at toy stores, the OMSI Science Store, 503-797-4626, or Flinn Scientific, www.flinnsci.com)	3 per class		
2-liter bottles	2 per class		
salt	3 tablespoons		


isotonic solution
water
water
hypertonic solution
water
water
hypotonic solution
water
water
salt molecule

DNA Extraction

Learning Objectives: *Students learn about DNA, cell structure, and basic chemical separations.*

GRADE LEVEL

4–8

SCIENCE TOPICS

Solutions and Mixtures
Techniques
Organic and Biochemistry

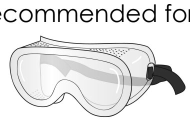
PROCESS SKILLS

Describing and Defining
Explaining
Evaluating

GROUP SIZE

1–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students extract DNA from strawberries.

STUDENT SUPPLIES

see next page for more supplies

strawberries
sealing plastic bags
dish soap
salt
meat tenderizer
isopropyl alcohol, etc.…

ADVANCE PREPARATION

see next page for more details

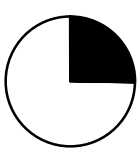
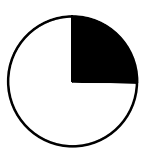
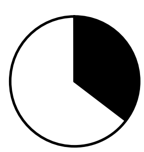
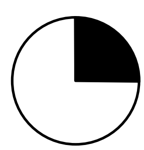
dilute soap
mix tenderizer and salt together, etc.…

OPTIONAL EXTRAS

DEMONSTRATION
Modeling the Procedure (p. C - 22)

EXTENSIONS
Animal DNA (p. C - 29)
Other DNA Sources (p. C - 30)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes the day before	**15 minutes**	**20 minutes**	**15 minutes**

SUPPLIES

Item	Amount Needed
strawberries	1 per group
sealing plastic bags (e.g., Ziploc™)	1 per group
liquid dish soap	½ teaspoon per group
99% isopropyl alcohol (or lower, e.g., 70% rubbing alcohol)	¼ cup per group
meat tenderizer **OR** papaya or pineapple juice	1 tablespoon per class **OR** ¼ cup juice per class
salt	1 tablespoon per class
tall, clear, narrow plastic cups (8 oz. or 12 oz.)	2 per group
plastic spoon	1 per group
pop-top squeeze bottles (e.g., water or sports drink)	1 per group
freezer or bucket of ice	1 per class

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Strawberries:
- Purchase fresh or thawed, green tops on or off.

Isopropyl alcohol:
- 99% isopropyl alcohol is best.
- 90% or 70% (rubbing alcohol) will work also.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

Soap solution:
- Dilute liquid dish soap with water: one part soap or detergent to two parts water.
- If possible, leave the soap mixture in a refrigerated place until immediately before use.

Either—meat tenderizer/salt mixture:
- Mix 1 tablespoon salt with 1 tablespoon powdered meat tenderizer in a plastic cup.

Or—papaya or pineapple juice:

- ❑ Use 1 cup of fresh, frozen (diluted as directed), or canned juice.
- ❑ Make sure juice contains raw, uncooked fruit juice.

Notes and Hints

- ❑ Keep the isopropyl alcohol very cold—use the freezer or ice bucket. Give to students as close to the start of the activity as possible.
- ❑ Pass out the pinches of meat tenderizer/salt mixture yourself or put the container at a central location for students. In the same way, you may pass out the juice samples yourself or make the juice, with a ⅛ teaspoon measure, available to all the students.
- ❑ Tall, narrow cups work best to see the layers of alcohol and strawberry mixture.

SETUP

For each group

- ❑ 1 sealing plastic bag
- ❑ ¼ cup **cold** isopropyl alcohol in a plastic cup
- ❑ 1 strawberry
- ❑ ¼ cup soap solution in pop-top squeeze bottle
- ❑ 1 teaspoon measure
- ❑ 1 clear plastic cup (6 oz. or larger, tall and narrow works best)

At a central location (or with the teacher)

- ❑ sponges and towels for clean up
- ❑ a bucket of ice or access to a freezer
- ❑ **Either—**meat tenderizer/salt mixture (2 tbsp) in a plastic cup **Or—**papaya or pineapple juice (1 cup) in a plastic cup, with
- ❑ ⅛ teaspoon measure

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will explore some of these questions by looking at the DNA from strawberries.

What do you think of when you hear the term "DNA"?

Most likely students have heard the term in daily life through newspapers, radio, or television. It may come up in stories related to crime solving, inheriting traits, treatments for disease, or identifying remains after an accident.

What sorts of things have DNA?
All living things have DNA, including plants, animals, fungi, bacteria, etc. Some viruses have DNA. Rocks, water, clouds, and other non-living things do not have DNA.

What characteristics of people does DNA influence?
DNA is in charge of physical attributes like height, hair color, eye color, etc. Dyed hair, colored contacts, tattoos, etc., are not determined by DNA. Things like interests, hobbies, and weight can be influenced by DNA but are also affected by how people grow up. Many scientists are still researching exactly which characteristics of people are determined by DNA and what are influenced by their environment.

Where do people/living things keep their DNA?
Many answers are possible, but students should know that a copy of DNA is kept in each cell in a living organism. Cells are surrounded by protective barriers (cell walls and membranes, see Explanation) that help organize and keep the DNA safe.

If we want to get the DNA out of living things to a place where we can see it, what do we need to do?
The DNA needs to be taken out of the cells. We need to get a source of DNA (i.e., something living), break down its cell walls and membranes, and then separate the DNA out from everything else in the cell. Students do this in this experiment.

What do you think DNA looks like with the naked eye?
Students can draw pictures, or write a sentence or two. The double helix structure might come up, or the "x" like structure of a chromosome. Individual molecules of DNA are too small to see even with microscopes (scientists use X-rays). On the other hand, thousands of strands of DNA all clumped together are visible even to the naked eye.

TEACHER DEMONSTRATION

Modeling the Procedure

For younger students, it is a good idea to model the steps in this reaction, especially layering the alcohol on top of the squished strawberry mixture without letting them mix.

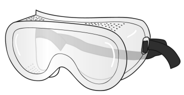
To layer the alcohol, tilt the strawberry cup and pour the alcohol SLOWLY down the side of the cup so it doesn't disturb the mixture. Alcohol and water readily mix together, so take care to pour the alcohol slowly onto the strawberry mixture.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page C - 34, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.



DNA Extraction

This handout is on p. C - 34.

SCIENTIFIC PROCEDURE

1. Place a strawberry in a plastic bag. Close the bag tightly. Smash and squish the strawberry until it forms a smooth paste.
   - What does the strawberry look like?
2. Open the bag.
3. Add one spoonful of the soap mixture into the bag.
4. Add a pinch of the mixture of meat tenderizer and salt into the bag.
5. Close the bag tightly and squish the contents until completely mixed.
   - How has the strawberry mixture changed?

Running Suggestions:

- The colder the alcohol is, the more DNA it will extract. It can be stored in the freezer without freezing solid.
- During the activity, you might pour out ¼ cup of cold alcohol to each group. This is safer than letting students walk around the room with alcohol and also allows the alcohol to stay cold longer.
- Make sure the plastic bag is closed tightly between steps.
- **The hardest step is layering the alcohol.** Make sure students DO NOT pour alcohol directly on top of the strawberry mixture at the bottom of the cup. They should tilt the cup and pour the alcohol SLOWLY so it flows down the side of the cup and floats on top of the strawberry mess. If the alcohol and water layers mix, the DNA will not precipitate out.

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by dirty hands or poisons in the lab.

Ongoing Assessment

- Why do we need to squish the strawberry? (To *free the DNA. Squishing breaks cell walls and releases the contents of the cell.)*
- Does anyone have a guess what the soap and tenderizer is for? *(The soap dissolves the cell and nuclear membranes that protect the DNA. The meat tenderizer and salt help control enzymes in the cells and keep the DNA structurally intact.*)
- Now that we have added soap and tenderizer, we have the DNA out of the cell. Why can't we see it? *(It's still dissolved in the water from the cell.)*

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Caution students to never put lab supplies into their mouths. Even if they are foods, they may be contaminated from other things in the lab.
- Waste isopropyl alcohol should be kept away from all sparks and flames. The small amounts used in this experiment may be poured down the sink drain with lots of water. All other materials can be thrown away as solid waste.

CAUTION: Isopropyl alcohol is flammable and poisonous.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What happened when you added the alcohol?
Snot, goo, white clumpy stuff, etc., came out of the strawberries and floated on top.

If this is DNA from the strawberries, does it look like what you expected?
Students will have various answers—some may have expected to see double helices or long ropy strands. In fact, people can't see those microscopic features. Instead, the thousands of strands of DNA from the strawberries look like white goo. NOTE: Some of the white, clumpy material may be coagulated protein mixed with the DNA.

Why would scientists want to extract DNA from cells?
This has a large number of answers, such as:

- *To change the DNA. Creating genetically modified foods, for example, could create crops that are resistant to certain pests/insects or that grow larger or faster.*
- *To analyze the DNA. Some diseases are linked to differences in people's DNA, so studying DNA can help scientists find cures and create vaccines.*

- *To identify the DNA. Since everyone has different DNA, it can be used to identify him or her. Forensic scientists, for instance, can identify criminals from DNA samples left at crime scenes. In the same way, biochemists can perform paternity tests or identify people from their remains after accidents.*

Could the DNA we extracted be used to identify or study the strawberries?
Unfortunately, DNA is quite fragile and the methods used in this experiment tend to break it apart. Scientists therefore use special chemicals and procedures to protect DNA. For example, they add chemicals to control the acidity of the solution. Scientists use other chemicals to cut DNA apart very precisely to look at one part at a time. This process can take several days to several weeks—not like on TV!

What other things could we extract the DNA out of?
In principle, scientists can extract the DNA from any living thing, and many spend their careers doing just that. (Students are encouraged to try the other foods mentioned in the Extensions to this activity.)

Note that although any living thing has DNA that can be extracted, the method in this activity is crude and quick and works well for only a few living objects. DNA is fragile and it is difficult to extract a whole DNA molecule (a chromosome) intact. Scientists use other methods to extract DNA from different organisms.

EXPLANATION

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

In this activity, students extract the DNA from strawberries using only salt, soap, and alcohol. Students may be very surprised at how much DNA is recovered in this simple procedure. Strawberries are used in this activity because they have a lot of DNA that comes out easily and is very visible.

BACKGROUND FOR ALL GRADES:

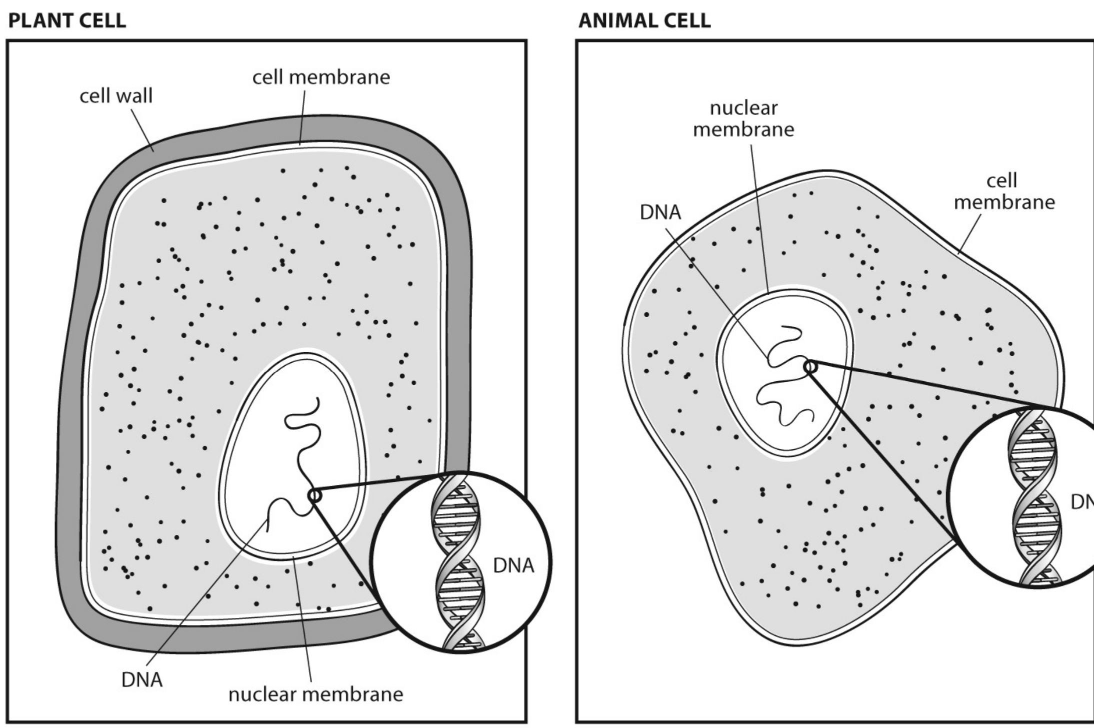
All living things are made of cells, and each cell contains a molecule called **DNA**. DNA carries the genetic information that determines gender, physical appearance, vulnerability toward disease, and many other parts of who we are. Every cell in our body contains DNA. Even though cells can only be seen under a microscope, an uncoiled piece of DNA can be 2.8 inches (7.2 centimeters) long!

Getting at the DNA

Plant and animal cells store their DNA in the **nucleus**, a small compartment inside each cell that is surrounded and protected by the **nuclear membrane** (see Figure 1 below). A **membrane** is a flexible, thin film that only water and a few special chemicals can pass through. The **cell membrane** surrounds and protects the entire cell. Adding detergent or soap breaks the nuclear and cell membranes, releasing the DNA.

Plant cells, but not animal cells, also have a rigid **cell wall** around the outside of the cell. The students must smash the strawberry in the bag to break the cell walls and expose the membranes inside to the soap or detergent.

Once the DNA has been released, the meat tenderizer (or pineapple or papaya juice) helps untangle and unfold the DNA from the other parts of the cell.



Protecting the DNA

Breaking the nuclear membrane exposes the DNA to reactive and possibly dangerous chemicals in the cell. To slow down these chemical reactions, which might damage or chop up the DNA, students use cold ingredients and add cold alcohol.

Separating Out the DNA

Although it is free to float around, the DNA is still dissolved in water after it escapes the membranes and cell wall. Students add alcohol, which floats on top of the water, to lift the DNA out of the water and to separate it from the rest of the cell debris. Since the DNA does not dissolve in alcohol, it **precipitates** (turns to a solid) in the alcohol layer. It is visible as a kind of white goo.

EXTRA BACKGROUND FOR 6–8 GRADES:

Lipid Structure of Cell Walls and Membranes

In this activity, students add soap to **lyse** (break open) the cell and nuclear membranes and release the DNA. Soap dissolves these membranes because they are basically layers of oil that surround the cell.

In other words, dish soap destroys cell membranes in the same way that it cleans oil off dishes and pans. Cell membranes and oil are both made of molecules called **lipids.** Lipids are large molecules that have two parts: a small, compact **hydrophilic** head and a long, dangling **hydrophobic** tail. (Hydrophilic means attracted to water, and hydrophobic means repelled by water.) In lipids, most of the molecule (the tail) is repelled by water, while the tiny head is attracted to water.

This head and tail structure of lipids allows them to arrange as large, two-layer sheets when they are in water. The sheet structure allows the hydrophilic, water-loving heads to be exposed to the water, while the hydrophobic, water-hating tails can be tucked into the interior of the sheet. The cell and nuclear membranes are such sheets of lipids, each with the water-attracting heads on the outside and the water-repellant tails on the inside.

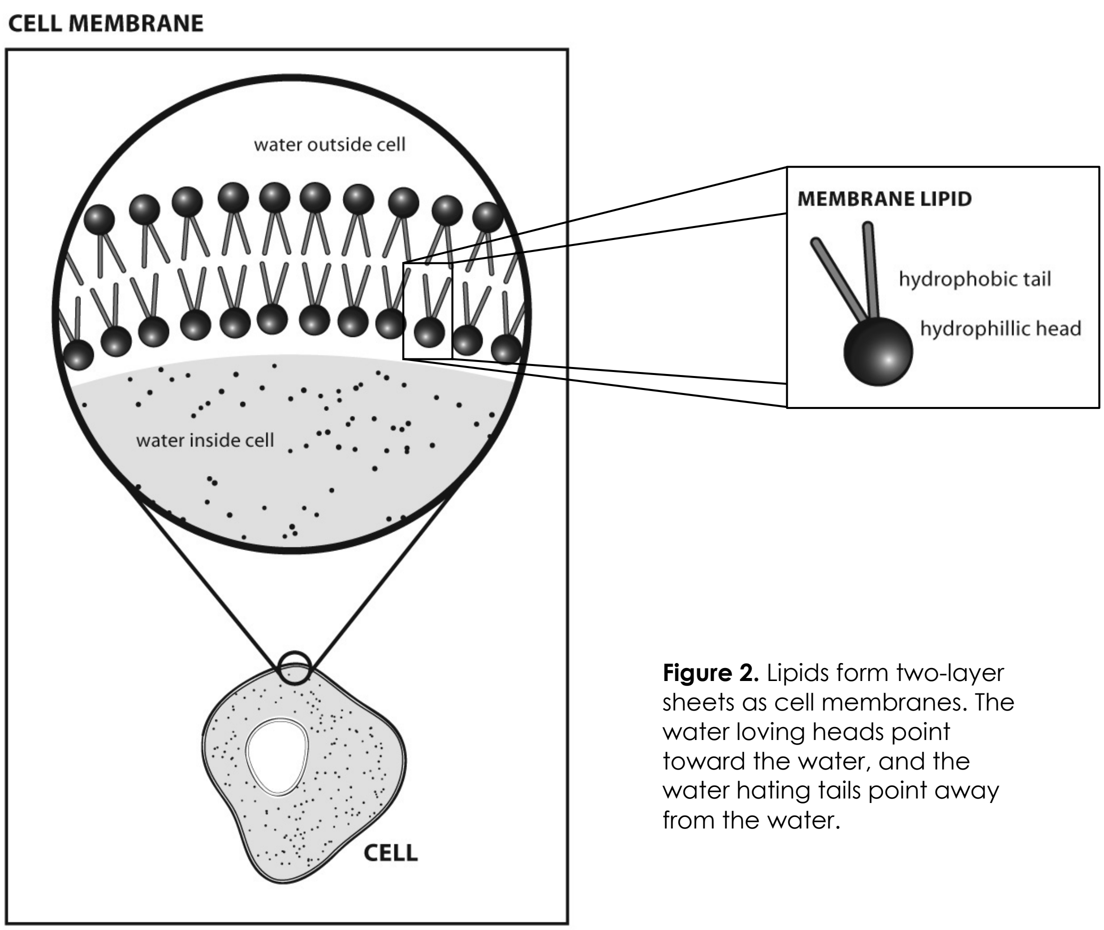


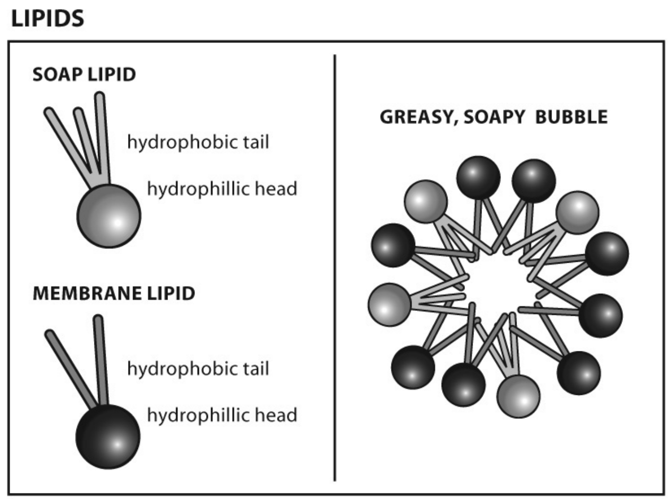
Figure 2. Lipids form two-layer sheets as cell membranes. The water loving heads point toward the water, and the water hating tails point away from the water.

Soap molecules are also lipids, just like the molecules in the membranes, but with one key difference: their hydrophilic, water-loving head is more able to dissolve in water—yet they still have a bit of a hydrophobic, water-hating tail. This means that they are still "lipid enough" to mix with the lipids in the cell membrane, but also "water enough" to mix with the water around the membrane. Because they can mix with lipids and water, soaps and detergents move into the membranes and break them apart into greasy, soapy bubbles (see the picture below).

Figure 3. Lipids have two parts: a hydrophobic (water hating) tail and a hydrophilic (water loving) head.

Soaps are lipids and so are the membranes in cells.

Soap lipids are different from membrane lipids because their hydrophilic "heads" are more "water loving" and more able to mix with water.



The membrane lipids and the soap lipids form little droplets with the membrane molecules broken up between soap molecules.

Protecting the DNA

To prevent **viruses** and **bacteria** from invading the cell with their DNA, cells have **enzymes** (called **DNase enzymes**) that chop up any DNA floating around outside the nucleus. Once the strawberry DNA is out of the nucleus, it becomes vulnerable to these enzymes. The students use cold ingredients to protect the DNA from DNases. Since reactions are slower at lower temperatures, using cold alcohol and other cold ingredients slows down the DNase reactions that break down DNA.

Meat tenderizer also helps to protect the DNA. Meat tenderizer contains another two enzymes, **bromelain** and **papain**, which are extracted from pineapples and papayas, respectively. (Pineapple and papaya juice perform the same function in this experiment as meat tenderizer.) When DNA is packaged in the nucleus, it is wound tightly around **proteins**. Bromelain and papain enzymes break down these proteins and release the DNA with minimal breakage.

Separating the DNA

DNA is **soluble** in water, but not in salty water. All the other cell contents are soluble in water and salt water. This difference in solubility allows students to separate DNA from the rest of the cell. Students add salt to the mixture to force the DNA out of the solution of water, strawberries, and soap.

> For more information on this process of separating substances according to their solubility, see the activity **Salting Out**.

DNA is not soluble in alcohol. When the DNA leaves the salty water mixture, it comes into contact with the alcohol and cannot dissolve. When DNA comes in contact with alcohol, it uncoils and **precipitates** (turns into a solid that forms from a liquid solution). All the other cell contents stay in the salty water solution.

Strawberries Have a Lot of DNA

Strawberries are **octoploid**, which means they have eight copies of their genetic material. (As a comparison, humans are **diploid**, since we have two copies of our genetic material.) This large volume of DNA ensures that even if the procedure is not very accurate, or if mistakes are made, enough DNA can still be extracted to be visible.

EXTENSIONS

Extension A: Animal DNA

Extract DNA from animal cells and compare it to the extraction from plant cells.

Extra Supplies

- ❑ source of animal DNA (calf liver or thymus work well)—about 1 tablespoon per group
- ❑ blender

Extra Instructions

- ❑ Use the same procedure as the regular activity, but puree the liver or thymus in a blender just before class. (These items don't squish in bags very well.) Students should receive a strawberry-size amount of the animal source.
- ❑ After the procedure, compare the animal DNA to the plant DNA from strawberries. How is it the same and different?

> **CAUTION: Advise students using these raw meat products to wash their hands thoroughly with soap and warm water after handling them.**

Explanation

Animal DNA may separate more cleanly than plant DNA. Plant cells have cell walls, which can separate out in the solution and be visible as a third layer. Because animal cells lack cell walls, this layer doesn't appear.

Extension B: Other DNA Sources

Students can try to extract DNA from other living things using the same procedure as for strawberries.

Extra Supplies

- other sources of DNA (some good ones are: wheat germ, spinach, peas, onions, broccoli, bananas, and zucchini)—use about 1 tablespoon of each per student group. Frozen foods work fine.
- blender—1 per class

Extra Instructions

Follow the same procedure as before but with the following changes:

- Firm sources (wheat germ, broccoli, onions, or zucchini) should be pureed in a blender or food processor immediately before use.
- If possible grind the wheat germ in a coffee grinder first. Then soak in warm water 5–10 minutes before blending.

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES

Genetically Modified Organisms

Find articles about genetically modified organisms (GMOs). What products contain GMOs? What are the advantages and disadvantages to GMOs? Since this is a controversial topic, stress to students the importance of getting scientific summaries and not just information from advocacy groups.

Discovery of DNA's structure

Scientists knew information was somehow stored and passed on between generations but didn't know details. Use one of the books listed in the Resources section to learn about how DNA's structure was discovered.

BIOLOGY

Cell Biology

Discuss the parts of the cell and their functions.
Discuss the differences between animal and plant cells.

RESOURCES

Web – http://learn.genetics.utah.edu/units/activities/extraction/
This site has excellent pictures of the extraction process with diagrams of how detergent breaks apart fats and cell membranes, as well as where in the cell the DNA is stored. The Frequently Asked Questions section has additional information.

Web – http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The *Journal of Chemical Education* publishes online lesson plans for high school students on multiple topics. Under the topic, "Biochemistry," the lesson "Liver and Onions" uses a more complicated procedure to extract DNA.

Balkwill, Frances R., *DNA is Here to Stay*
Reading level: kindergarten to 4th grade
This gives a simple explanation of what DNA is and what it does in the body. This author also writes a series called "Enjoy Your Cells." This book is scientifically accurate and good for all ages.

Walker, Richard, *Genes and DNA*
Reading level: 4th to 8th grade
This book explores modern genetics, from an investigation of genes and their function to forensics, gene therapy, and cloning.

Claybourne, Anna et al., *Usborne Internet Linked Introduction to Genes and DNA*
Reading level: 4th to 8th grade
Beautiful artwork takes you deep inside a cell. This book also explains genetically modified foods, the Human Genome Project, gene therapy, designer babies, and DNA testing.

Watson, James D., *The Double Helix: A Personal Account of the Discovery of the Structure of DNA*
Reading level: 10th to 12th grade
This is an autobiographical account from one of the discoverers of the structure of DNA. Tends to be a bit dramatic.

Maddox, Brenda, *Rosalind Franklin: The Dark Lady of DNA*
Reading level: 10th to 12th grade
Rosalind Franklin conducted crucial research that led to the discovery of the double helical structure of DNA. Because of her unpublished data and photographs, Francis Crick and James Watson were able to publish their work on the structure of DNA.

VOCABULARY

bacteria: very small organisms each made of just one cell

bromelain: enzyme from pineapples that cuts up proteins

cell membrane: a thin barrier that surrounds the contents of plant and animal cells; provides structure and organization to the cell and controls the passage of water and other chemicals both into and out of the cell

cell wall: the rigid outermost barrier that surrounds the cell membrane; found in all plants and some algae, bacteria, and fungi; absent from all animal cells

diploid: having two copies of genetic material

DNA: **D**eoxy-ribo**N**ucleic **A**cid; a long molecule found in the nucleus of a cell and shaped like a double helix; associated with the transmission of genetic information

DNase: an enzyme that breaks down DNA; "-ase" stands for enzyme

enzyme: complex protein produced by cells; acts to speed up a specific biochemical reaction

hydrophilic: attracted to water; easily absorbs water and dissolves in water

hydrophobic: repelled by water; unable to absorb water or dissolve in water

lipids: group of organic molecules that includes oils, fats, and waxes; lipids, carbohydrates, and proteins make up the main structures of cells

lyse: to break open or split

membrane: a thin film that forms a barrier

nuclear membrane: similar to the cell membrane; surrounds the contents of the nucleus, separating it from the rest of the cell

nucleus: a compartment inside the cell that contains the cell's genetic information

octoploid: having eight copies of genetic material

papain: enzyme from papayas that cuts up proteins

precipitate: to come out of a liquid solution as a solid

proteins: a large, complex biological molecule found throughout the body; hormones, enzymes, and antibodies are all proteins, as are many of the structural parts of the body

soluble: able to dissolve in a particular substance

virus: a simple, small infectious agent made from genetic material with a thin protein coat; cannot live without entering a cell so is not considered living

DNA Extraction

SCIENTIFIC PROCEDURE

1. Place a strawberry in a plastic bag. Close the bag tightly. Smash and squish the strawberry until it forms a smooth paste.
   - What does the strawberry look like?

2. Open the bag.

3. Add one spoonful of the soap mixture into the bag.

4. Add a pinch of the mixture of meat tenderizer and salt into the bag.

5. Close the bag tightly and squish the contents until completely mixed.
   - How has the strawberry mixture changed?

6. Open the bag and pour the contents into a clear plastic cup.

7. SLOWLY pour alcohol so it runs down the side of the cup and gently floats on top of the strawberry mixture.
   - **You can tilt the strawberry cup to make this easier. Continue to carefully pour until about 1" of alcohol is on top of the strawberry mixture.**

8. Put the cup down and wait 30–60 seconds.
   - What is happening to the strawberry mixture?

9. Clean up your area.
   - Follow your teacher's instructions.

SUPPLY WORKSHEET

This worksheet is available online at **www.omsi.edu/k8chemistry**.

DNA Extraction

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
strawberries	1 per group		
sealing plastic bags (e.g., Ziploc™)	1 per group		
liquid dish soap	½ teaspoon per group		
99% isopropyl alcohol (or lower, e.g., 70% rubbing alcohol)	¼ cup per group		
meat tenderizer **OR** papaya or pineapple juice	1 tablespoon per class **OR** ¼ cup juice per class		
salt	1 tablespoon per class		
tall, clear, narrow plastic cups (8 oz. or 12 oz.)	2 per group		
teaspoon measure	1 per group		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
freezer or bucket of ice	1 per class		
Extension A			
source of animal DNA (calf liver or thymus work well)	½ cup per class		
blender	1 per class		
Extension B			
other sources of DNA (wheat germ, spinach, peas, onions, broccoli, bananas, zucchini)	1–2 cups per class		
blender	1 per class		
Teacher Demonstration			
no extra supplies needed			


pour alcohol
SLOWLY

¡La zanahoria torcida!

PROCEDIMIENTO CIENTÍFICO

1. Marca tus bolsas.
   - Marca una bolsa como "Sal" y la otra bolsa como "No Sal."

2. En la bolsa identificada como "Sal" agrega 1 cucharada de sal.

3. Agrega dos zanahorias en cada bolsa.
   - Sacude la bolsa para mezclar las zanahorias y la sal.
   - Espera alrededor de 30 minutos.

4. Observa tus zanahorias.
   - ¿Cómo cambiaron las zanahorias?
   - ¿Cuál es la diferencia entre las zanahorias de cada bolsa?
   - ¿Cómo se sienten las zanahorias cuando las doblas?

5. Limpia tu área de trabajo.
   - Sigue las instrucciones del maestro(a).

¡La zanahoria Torcida!

PROCEDIMIENTO CIENTÍFICO—Extensión B

1. Identifica tus vasos.
    - Escribe tu nombre en todos los vasos.
    - Identifica los vasos de la siguiente manera: "agua," "½ cucharadita de sal," "1 cucharadita de sal," "2 cucharaditas de sal."

2. Agrega sal y agua a los vasos.
    - Con cuidado, agrega la cantidad correcta de sal en los vasos correspondientes.
3. Agrega agua a los vasos de manera que cada uno tenga la misma cantidad de líquido La cantidad no es importante, excepto que tiene que ser la misma.
    - Mezcla las soluciones de cada vaso.
4. Agrega dos zanahorias en cada vaso. Déjalos así hasta el día siguiente.
5. Al día siguiente observa tus zanahorias.
    - En comparación a la zanahoria ¿qué soluciones son hipotónicas (menos sal)? ¿Cómo lo sabes?
    - En comparación a la zanahoria ¿qué soluciones son hipertónicas (más sal)? ¿Cómo lo sabes?
    - En comparación con la zanahoria ¿qué solución es isotónica (igual cantidad de sal)?¿Cómo lo sabes?
6. Limpia tu área de trabajo.
    - Sigue las instrucciones del maestro(a).

Extracción de ADN

PROCEDIMIENTO CIENTÍFICO

1. Coloca una fresa dentro de la bolsa de plástico. Cierra bien la bolsa. Aplasta y aprieta la fresa hasta que se forme una pasta uniforme.
   - *¿Cómo se ve la fresa?*

2. Abre la bolsa.

3. Agrega una cucharada de la mezcla de jabón dentro de la bolsa.

4. Agrega una pizca de la mezcla de suavizante de carnes y de sal dentro de la bolsa.

5. Cierra bien la bolsa y aprieta bien el contenido hasta que se mezcle completamente.
   - *¿Cómo ha cambiado la mezcla de la fresa?*

6. Abre la bolsa y coloca su contenido en un vaso de plástico transparente.

7. LENTAMENTE agrega el alcohol para que se deslice por uno de los lados del vaso y flote por encima de la mezcla de fresa.
   - Para facilitar este paso puedes inclinar un poco el vaso. Continúa agregando cuidadosamente el alcohol hasta que haya 1 pulgada de alcohol sobre la mezcla de fresa.

8. Coloca el vaso sobre la mesa y espera de 30 a 60 segundos.
   - *¿Qué le está ocurriendo a la mezcla de fresa?*

9. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Concepts

Living things are made of many simple and complex molecules.
Chemical reactions in living things are necessary for survival.

Words to know

acid - a compound that increases the number of hydrogen ions (H+) in solution with water. All acids have a pH below 7.
amino acid - a small molecule that is a building block of a protein; long chains of these make proteins.
atom - a very, very small particle that makes up all matter.
base - a compound that decreases the number of hydrogen ions (H+) in solution with water. All bases have a pH above 7.
biochemistry - the study of chemical reactions that occur within living things.
carbohydrate - a complex molecule made of many sugars.
catalyst - a substance that helps chemical reactions occur but is not changed in the reaction.
chemical reaction - an interaction of atoms or molecules to form new elements or molecules.
enzyme - a protein that acts as a catalyst.
DNA - DeoxyriboNucleic Acid; this complex molecule carries genetic instructions for living things.
indicator - a chemical that changes color with changes in pH.
matter - a group of at least two atoms held together in a definite arrangement.
molecule - a small particle made of two or more connected atoms.
pH - a scale that measures relative acidity and basicity.
protein - a complex biological molecule that may act as a structural element or may assist biochemical reactions; hair, nails, skin, muscle are all proteins.
sugar - simple biological molecule that provide energy for living things.

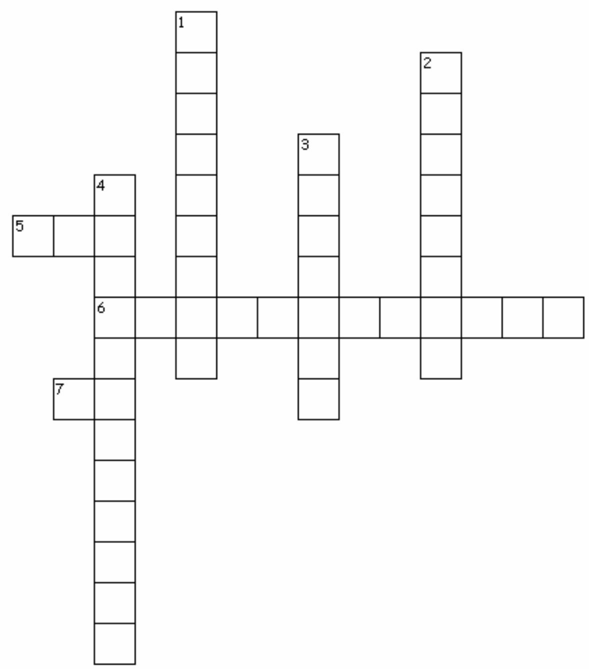
Use the
Words to Know
to complete the puzzle below.

Down

1. Cabbage juice, an _____, turns deep red in acidic solutions.
2. A _____ helps a chemical reaction to occur but is not changed during the reaction.
3. An enzyme is a special type of _____.
4. Pasta, crackers, popcorn, and bread are all examples of a _____.

Across

5. _____ carries genetic instructions in all living things.
6. _____ is the study of the chemical reactions of living things.
7. Vinegar is an acid since its _____ is below 7



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CheM LaB

Take-Home Activities

Biochemistry

Yeast Balloons

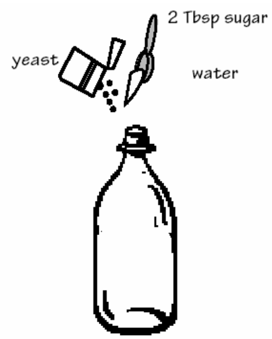
Can biochemistry blow up a balloon?

Materials:

one small clear plastic soda bottle
warm water
one package active yeast
2 tablespoons sugar
one large balloon (8" or 9" size)

To do and notice:

1. Half fill the bottle with warm water.
   - **Why might hot or cold water not work?**
2. Add the yeast and sugar to the bottle.
3. Cap the bottle tightly and shake it well.
4. Uncap the bottle and stretch the neck of the balloon over the bottle opening for a tight seal.
5. Sit back and watch. After about 20 minutes you should see the balloon begin to inflate. This process will continue over the course of several hours.
   - **Why does the balloon inflate?**



A closer look:

Yeast are tiny organisms that live well at warm temperatures. The yeast will die in water that is too hot and will not be active in water that is too cold.

Yeast use sugar as food. In a biochemical reaction called "fermentation," the yeast breaks down the sugar ($C_{12}H_{22}O_{11}$) into ethyl alcohol (C_2H_5OH) and carbon dioxide gas (CO_2). The carbon dioxide gas creates the foam and inflates the balloon. Brewers and bakers both use this reaction. Brewers use yeast to create bubbly alcohol. Bakers use yeast to make bread rise.

Egg Osmosis

A four-day eggsperience!

Materials:

2 raw eggs in their shells
vinegar
corn syrup
water
two wide-mouthed jars deep

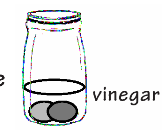
CAUTION: **Always wash your hands thoroughly with soap after handling raw eggs, which are a common source of salmonella bacteria.**

To do and notice:

Days 1-2

Put the eggs in a jar. Cover the eggs with vinegar. Keep the eggs in vinegar for two days. Look for changes on the surface of the egg during the two days. As the egg shell reacts with the vinegar, the reaction produces carbon dioxide gas bubbles.

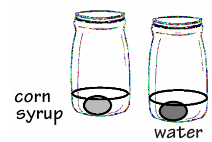
- **What happens to the shells?**



Day 3

Carefully remove each egg from the vinegar. Rinse the eggs and the jars with water. Gently feel the eggs.

Put one egg in each jar. Cover one egg with water and cover the other egg with light corn syrup. Let the eggs sit overnight.



Day 4

Observe both eggs (you can gently pick them up).

- **What are the differences between them?**

A closer look:

The membrane around the egg is like a very fine mesh. Small molecules like gases and water can pass through the membrane, but larger molecules like proteins or sugars cannot. When water passes through the membrane, this is called "osmosis."

Corn syrup is a very concentrated solution of large molecules. When the egg is in corn syrup, water from inside the egg flows out to dilute the corn syrup. The egg shrivels. In water, solution inside the egg is more concentrated than the water outside. The water flows into the egg in an attempt to dilute the white of the egg. This makes the egg swell up to its full size.

Cabbage Juice Indicator

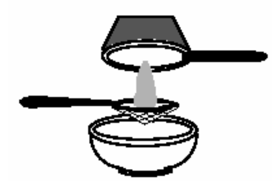
Test the pH of household products!

Materials:

large pot half full of water
water
½ head of RED cabbage
chopping knife or food processor
strainer
large bowl
spoon
plastic cups
baking soda
vinegar

To do and notice:

1. With an adult's help, heat the pot of water until the water is very hot.
2. With an adult's help, chop the cabbage with a knife or food processor.
3. Place the cabbage pieces in the pot and cover them with the hot water. Let the cabbage pieces sit for 2 minutes in the hot water.
   - **What happens to the color of the water?**
4. Place the strainer in the bowl. Pour the cabbage pieces and cabbage juice through the strainer, collecting the juice in the bowl.
5. Use the spoon to put cabbage juice in some plastic cups. Add a few drops of vinegar to one of the cups.
   - **What color is the mixture?**
6. Add some baking soda to another of the cups.
   - **Is the color different?**
7. Find other things to add to the cabbage juice. Examples might include milk, lemon juice, soda water, soap, antacids, and aspirin.



A closer look:

Red cabbage contains a chemical that changes its shape depending on whether it is surrounded by an acid or base. When its shape changes, so does its color. The cabbage juice is purple in water (neutral), red in vinegar (acid), and blue-green in baking soda (base).

Some other plants also have chemicals that change color. Try this with flower petals, juices, or berries.

Cleaning with Dirt

Learning Objectives: *Students learn that dirt can be used to trap runoff pollution, but that there are limits to what dirt can filter.*

GRADE LEVEL

5–8

SCIENCE TOPICS

Solutions and Mixtures
Techniques
Environmental Chemistry

PROCESS SKILLS

Comparing and Contrasting
Making Models
Hypothesizing

GROUP SIZE

3–4

SNEAK PEAK inside …

ACTIVITY

Students build a water filter using sand and plastic bottles.

STUDENT SUPPLIES

see next page for more supplies

20 oz. or 1-L plastic bottles
artificial pollutants (tempera, vegetable oil, sticks, rocks)
sand, tape, scissors, etc.…

ADVANCE PREPARATION

see next page for more details

Construct bottle filters
Mix up artificial pollutants, etc.…

OPTIONAL EXTRAS

DEMONSTRATIONS
Modeling the Activity (p. D - 4)
Activity Clean Up (p. D - 4)

EXTENSIONS
Inquiry Opportunity: Build a Better Filter (p. D - 8)
Filter Acid Rain (p. D - 8)
Measure Filtration Rates (p. D - 9)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up

15 minutes	**30 minutes on day one**	**20 minutes on day two**	**5 minutes**

SUPPLIES

Item	Amount Needed
plastic bottles, 20 oz. or 1-L (e.g., soda or water bottles)	2 per group
plastic caps from plastic bottles	1 per group
drill with ⅛" bit (or small screw and screwdriver)	for teacher
scissors	1 per group
masking tape	1 roll per group
sand	2–3 cups per group
cotton balls (optional)	1 per group
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	1 per group
water	2 cups per group
artificial pollutants (vegetable oil, dilute tempera paint, dirt, sticks, rocks, paper, Styrofoam)	1–2 tablespoons per pollutant per group
plastic cups	1 per pollutant per group
plastic spoons	1 or 2 per pollutant per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Bottle Caps:

- Drill a hole in each plastic cap with the ⅛" bit. Alternatively, use the screwdriver and small screw to make a hole in the lid (wiggle the screw loose after driving it in).
- The hole needs to be large enough to allow water to flow at an observable rate, but slow enough that the water interacts with the sand in the filter.

Water Bottles:

- Fill pop-top squeeze bottles with about 2 cups of water.
- Label these bottles "water."

Artificial Pollutants:

- ❑ If you are using tempera paint as a pollutant, add just enough paint to color some water. Use this solution as the pollutant in the activity.
- ❑ You may decide to have groups share pollutants.
- ❑ Put 1–2 tablespoons of each pollutant into plastic cups for each group.
- ❑ Add 1 or 2 plastic spoons to each cup.
- ❑ Label the plastic cups with their contents.

Filter Assembly

- ❑ Students can complete the first step of the procedure, assembling the filters, in one class period. The next day, they can complete the activity.
- ❑ Alternatively, you or a group of parent volunteers may set up the filters before the activity.

Notes and Hints

- ❑ The sand may fall through the hole when the filter is assembled. If this is the case, insert a cotton ball in the lid before adding the sand to the filter.

SETUP

<u>For each group on Day One</u>

- ❑ 2 plastic bottles
- ❑ scissors
- ❑ roll of tape
- ❑ lid with pre-drilled hole
- ❑ sand
- ❑ cotton ball (optional)

<u>For each group on Day Two</u>

- ❑ assembled filter from previous day
- ❑ water in plastic pop-top bottles
- ❑ artificial pollutants in cups with spoons

<u>At a central location (or with the teacher)</u>

- ❑ towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

What happens in your neighborhood when it rains heavily? Have you observed a difference in areas that are paved compared to unpaved?
Perhaps students have seen gutters running full and fast directly into sewers or areas of grass and trees with water soaking into the ground (or running off in muddy streams).

What substances might a heavy rainfall wash off a busy street? A household lawn? A commercial parking lot? Are they all pollutants?
Gasoline, oil, anti-freeze, hydraulic fluid, fertilizers, pesticides, silt, sand.

What are some ways to limit the amount of polluted runoff entering rivers and lakes?
Allow students to brainstorm ways and use any ideas related to filtering to introduce the activity. Point out that other valid ideas are just as valuable.

In this activity students will learn that dirt can be used to trap runoff pollution. Students also learn that there are limits to what dirt can filter.

TEACHER DEMONSTRATION

Modeling the Procedure
You may want to demonstrate how to assemble the filter from the plastic bottles and sand.

After-Activity Cleanup
As students clean up, collect the used sand into a large aquarium. During the discussion, refer to the sand and compare how dirty the sand became. Even if students' water does not appear "clean," the sand will appear to be "dirty."

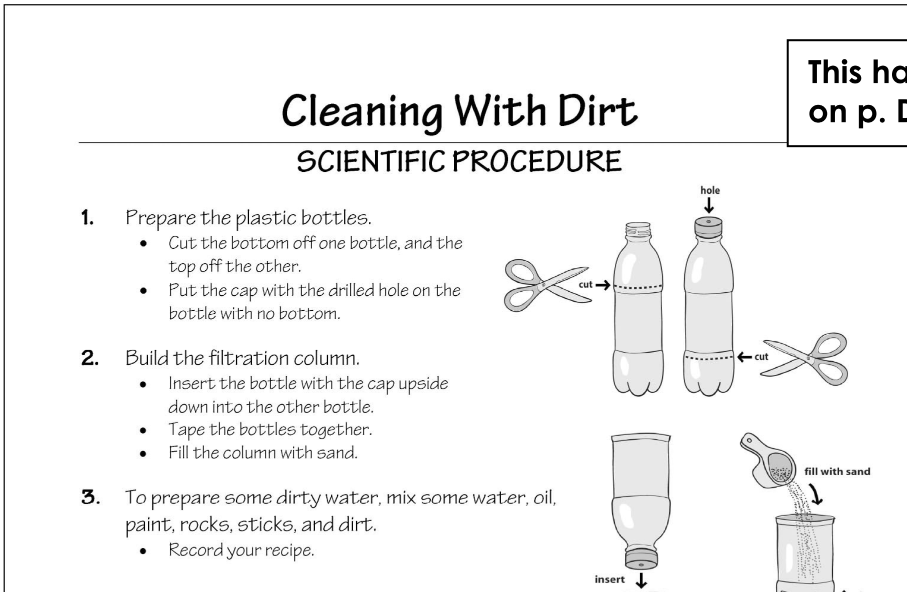
Also, use this to demonstrate what will happen after a heavy rain. Pour water on top of the sand in the aquarium. Some pollutants (oil, paint, Styrofoam) will rise into the water layer. Explain that the pollutants are not completely trapped in the soil but will leach out and become runoff to pollute a new area.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page D - 12, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

This handout is on p. D - 12.



Cleaning With Dirt

SCIENTIFIC PROCEDURE

1. Prepare the plastic bottles.
   - Cut the bottom off one bottle, and the top off the other.
   - Put the cap with the drilled hole on the bottle with no bottom.
2. Build the filtration column.
   - Insert the bottle with the cap upside down into the other bottle.
   - Tape the bottles together.
   - Fill the column with sand.
3. To prepare some dirty water, mix some water, oil, paint, rocks, sticks, and dirt.
   - Record your recipe.

Running Suggestions

- ❑ Monitor students as they cut the bottles as directed and assemble them into filtration columns. It is important that the bottles are taped together securely BEFORE the sand is added.
- ❑ The filters will be top heavy and may tip over. Encourage students to be careful and not bump the table. Also, students may try using tape to secure the bottom of their filter column to the table.

Ongoing Assessment

- ❑ Students can prepare their dirty water according to a specific recipe, or they can each make up their own mixture. Encourage students to record their recipe for dirty water.

It is vitally important that students carefully observe and record their observations of the dirty water. Students should also carefully observe the water after it is filtered. They can compare and contrast the water when it was "dirty" and when it is "clean."

You may want to instruct students to write their answers and draw pictures on a separate piece of paper so they will have more space to write.

Safety and Disposal Information

- As students clean up, they should return their sand to a large container. If you are doing the Teacher Demonstration, collect the sand into a large aquarium.

CAUTION: Do not allow students to pour their sand down the drain.

CAUTION: Do not allow students to drink their filtered water. Even though it may look clean, it is not safe for drinking.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What mixture did you use to create your dirty water?
Answers will vary.

What did your water look like before you poured it in the filter?
The oil floated on the water. The paint mixed with the water. Dirt and sticks were floating in the water.

What happened when you filtered your water?
All the solids stayed on top of the sand. The oil stayed in the sand. The paint took longer to go through the sand, so it stayed in the sand. The paint came out of the sand later.

What did the water look like after you filtered it? Is your water clean?
It looks clear, cloudy, etc. It's definitely cleaner but not quite drinking water.

Students will likely notice that the dirt was not able to filter everything. Some may even assert that the dirt did nothing to improve the purity of the water. At this point, direct students' attention to the aquarium where they dumped their sand after filtering. Pour water into the aquarium and stir the sand. All of the trapped pollutants will appear. From this, students should see that dirt can act as a filter, but it is limited in its capability.

EXPLANATION

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

Students create their own mixture of dirty water, and then pour it through a sand filter. Students then observe what materials the dirt filter could and could not clean from the water.

Chemistry of Filtration
All kinds of things can float and dissolve in water. To remove them and produce cleaner water, people use **filters**. Filters work in two ways. First, they physically block the passage of large items (e.g., sticks and pieces of plastic) by trapping them inside or on the surface of the filter. Second, they chemically attract many smaller items (e.g., small drops of oil floating in the water, floating bits of clay, etc.) and prevent them from passing through.

Filters use substances like sand, dirt, and charcoal to clean water because these substances are chemically similar to and therefore attract many common pollutants. For example, sand is an excellent filter for oily water because the oil is more attracted to the sand than it is to the water. Water pours through the sand quickly, but it takes longer for the oil because the sand slows it down.

In the same way, a famous person takes longer to cross a room full of people they know than it takes a stranger to cross the same room. The number of interactions might be the same, but the length of each interaction is different.

For more information on how substances are chemically similar, see the Explanation of **Salting Out**.

Water Cycle
Usually, rainwater soaks into the ground. This water evaporates, is taken up by plants, or becomes **groundwater**. Groundwater is water that is held underground in dirt or rocks. As dirty water soaks into the soil, the soil traps **pollutants**. This means that the soil is acting as a water filter. This process takes time, so the water needs to move through the ground slowly. Plants, rocks, and other natural barriers trap surface water and slow it down enough to be filtered.

Sometimes water cannot get to the ground easily. Buildings, roads, and houses are all considered **impervious cover** and block water from getting to the ground. The water then accumulates on the roofs, gutters, and pavement. In these places it can collect even more pollutants. The water collects from these places and then gains enough volume that it moves across the impervious cover quickly, becoming **urban runoff**. When and if this urban runoff eventually reaches the ground, it is sometimes moving too quickly to be filtered by the ground. This type of pollution is called **non-point source pollution** because the pollution is collected from many sources and cannot be identified as coming from one place.

EXTENSIONS

Extension A: Inquiry Opportunity—Build a Better Filter
Try changing variables in this experiment. For example:

- Filter Length—Investigate whether a longer column results in even cleaner water. Stack multiple inverted bottles filled with sand and run the dirty water through a longer filter.
- Number of Filtrations—Investigate whether multiple trials will result in cleaner water. Pour the filtered water through the sand repeatedly to see if the water becomes cleaner.
- Filter Material—Investigate which material makes the best filter. Try any of the following items instead of sand: dirt, potting soil, shredded paper, rice, kitty litter, charcoal, or gravel.

> For more information about experimental design, see the section ***Science Inquiry*** in the beginning of the Guide.

Extension B: Neutralizing Acid Rain
Make fake "**acid rain**" and watch the filter neutralize it. This can be an extra teacher demonstration or an activity for student groups.

> This extension requires students to have previous experience with acid-base indicators. The activity ***Of Cabbages and Kings*** is a good precursor activity.

Extra Supplies

- lemon juice—1 tsp. per group
- cabbage juice indicator (prepare as in ***Of Cabbages and Kings***)—1 cup per group
- substitute for sand in the filtration column
  Either—a mixture of half sand and half garden lime (which is powdered limestone)
  OR—¼- to ½-inch diameter marble chips or crushed limestone
  Marble is a common landscape material and is usually available as rocks with 1- to 3-inch diameter. You or an energetic team can crush these rocks with a hammer to a diameter of ¼- to ½-inch diameter.

> **CAUTION: If you choose to use a hammer and break up landscape marble rocks, wrap the rocks in old towels to prevent stray projectiles. Wear goggles when crushing marble rocks.**

Extra Instructions

- Mix the 1 cup of cabbage juice and 1 teaspoon of lemon juice together to make "acid rain." Make sure students know the red color of the juice shows the acid (lemon juice) in the water.
- Lemon juice is the only pollutant needed.

- Pour the acid rain solution through the column. Students should see the solution change color from pink (acid) to purple (neutral) or blue (basic) at the bottom.
- It may be helpful to pour one batch of acid rain through the sand filter to show that normal sand does not remove the acid from acid rain.

Explanation

Marble and limestone are made from calcium carbonate ($CaCO_3$). The calcium carbonate reacts with acid in water, producing hydrogen carbonate (H_2CO_3) and a neutral salt. Thus, the marble or limestone is able to **neutralize** the acid rain.
Most acid rain in the U.S. falls in the Northeast. There, engineers are lining lakes with limestone rock to help counter the effects of acid rain. Unfortunately, this is not a complete solution. The hydrogen carbonate (H_2CO_3) will further break down to produce water (H_2O) and carbon dioxide gas (CO_2). Carbon dioxide gas is known as an agent in global warming.

Another topic for discussion is the difference between a **physical change** and a **chemical change**. In the main activity, the filtration is a physical change. Even though there interactions between different chemicals, no new substances are being created when the polluted water travels through the filter. In this extension, there is a chemical change as the cabbage juice is neutralized from an acid.

Extension C: Measure Flow Rate

During the activity, students may notice that the water moves through the filters at different rates. Here is a way to quantify that difference.

Extra Supplies

- timer or a clock with a second hand

Extra Instructions

- Use a timer or a clock with a second hand to time 30 seconds.
- While students are doing the filtration, they should count the number of drops that come out of the filter in 30 seconds.
- After the activity, organize the filtered water in order from fastest filtration (most drops in 30 seconds) to slowest (fewest drops in 30 seconds).
- Observe the water. Do slow filters lead to cleaner water?

Explanation

Even though slower flow rates usually lead to cleaner water, this may not be the case due to different recipes of dirty water. Use this as an opportunity to discuss the importance of controlling variables.

For more information on experimental design, see the section **Science Inquiry** at the beginning of the Guide.

CROSS-CURRICULAR CONNECTIONS

ENVIRONMENTAL SCIENCE

Pond Study

Ponds and vernal pools are filled with runoff water. The quality of the runoff water plays an important part in the life of the pond. Use the resources listed to study a local pond.

Environmental Impacts

Research the impact of buildings, parking lots, and roads on runoff. Research ways to reduce groundwater pollution.

MATHEMATICS

Measure Impervious Cover

Find a scale map (or aerial photo) of the school grounds. On this map mark the areas that have impervious cover. Calculate the area of impervious cover and the total area of the school grounds. Then find out what percentage of the school grounds has impervious cover. Advanced students could make their own scale map of the school for calculations.

Find scale maps (or aerial photos) of your local area, a farming area, and a large city. Repeat the same calculations to find the percentage of impervious cover in these areas. Compare the calculations

RESOURCES

Web – http://pbskids.org/zoom/activities/sci/waterfilter.html
Web site gives directions on making a water filter similar to the one modeled here. Kids are encouraged to write in to the site and share their results.

Web – http://www.metro-region.org/
Metro is the regional government for the 3 counties and 25 cities in the Portland metropolitan area. At the bottom right is a link "for kids and schools" which describes lessons and videotapes available for teachers.

Web – http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf
The Environmental Protection Agency has good information about urban runoff.

Morrison, Gordon, *Pond*
Reading level: 3rd grade to 6th grade
Uses attractive ink drawings to describe the life cycle of a pond. Includes factual text about the animals and plants that live in a healthy pond.

Josephs, David, *Lakes, Ponds, and Temporary Pools (Exploring Ecosystems)*
Reading level: 5th grade to 8th grade
This activity book allows students to study a local pond. Includes detailed information about ponds and how sensitive they are to environmental factors. Also includes dichotomous keys to identify organisms living in the pond.

VOCABULARY

acid rain: clouds or rain droplets containing pollutants, such as sulfuric and nitric acid, which make them acidic

chemical change: when substances change their properties and their molecules change; examples include burning, rusting, forming a new material, creating gas bubbles, creating light

filter: a device, usually containing sand, charcoal, dirt, or some other porous material, that traps the contaminants in water when water passes through

groundwater: water that is held underground

impervious cover: material that blocks water from getting to the ground; pavement, buildings, roads, and sidewalks are examples

neutralize: to make chemically neutral (i.e., bring to a pH of 7); to make inert and less dangerous

non-point source pollution: pollution that accumulates from multiple sources

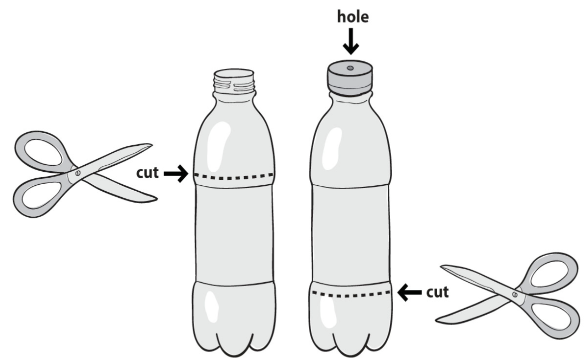
physical change: when substances change their properties without any changes to their molecules; examples include melting, freezing, boiling, creating or separating a mixture, cutting, denting, or scratching

pollutant: an agent that can potentially harm or contaminate a resource

urban runoff: excess water, often contaminated with pollutants, that tends to dump in streams and rivers before being filtered through the ground

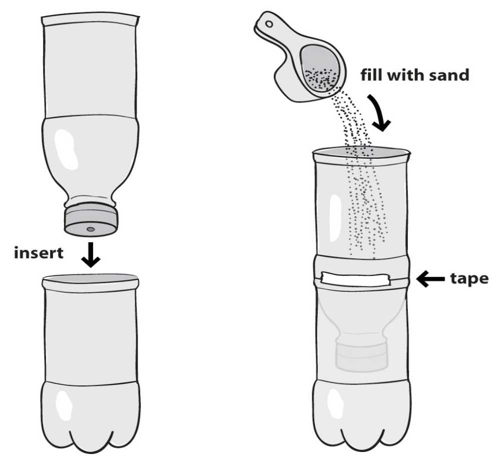
Cleaning with Dirt

SCIENTIFIC PROCEDURE



1. Prepare the plastic bottles.
   - Cut the bottom off one bottle and the top off the other.
   - Put the cap with the drilled hole on the bottle with no bottom.

2. Build the filtration column.
   - Insert the bottle with the cap upside down into the other bottle.
   - Tape the bottles together.
   - Fill the column with sand.



3. To prepare some dirty water, mix water, oil, paint, rocks, sticks, and dirt.
   - Record your recipe for dirty water.
   - What does your dirty water look like?

4. Pour your dirty water into the column, and watch it run through. When the dirty water has made it to the bottom, pour a cup of clean water on top of the column to chase out the dirty water.
   - Which ingredients are still in your water?
   - Which ingredients stayed in the sand?
   - Did some ingredients travel more slowly?

5. Clean up your area.
   - Follow your teachers instructions.

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Cleaning with Dirt

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
plastic bottles, 20 oz. or 1-L (e.g., soda or water bottles)	2 per group		
plastic caps from plastic bottles	1 per group		
drill with ⅛" bit (or small screw and screwdriver)	for teacher		
scissors	1 per group		
masking tape	1 roll per group		
sand	2–3 cups per group		
cotton balls (optional)	1 per group		
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	1 per group		
water	2 cups per group		
artificial pollutants (vegetable oil, dilute tempera paint, dirt, sticks, rocks, paper, Styrofoam)	1–2 tablespoons per pollutant per group		
plastic cups	1 per pollutant per group		
plastic spoons	1 or 2 per pollutant per group		
Extension A			
extra bottles for filters	amount varies		
extra sand for filters	amount varies		
other filter materials: dirt, potting soil, shredded paper, rice, kitty litter, charcoal, or gravel.	amount varies		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Extension B			
red cabbage	1 head per class		
knife, blender, or food processor	1 per class		
strainer	1 per class		
lemon juice	1 tsp per group		
crushed marble chips or crushed limestone	2–3 cups per group		
garden lime	1–2 cups per group		
hammers	1 per person crushing marble		
goggles	1 pair per person crushing marble		
Extension C			
timer or clock with a second hand	1 per group		
Teacher Demonstration			
After-Activity Clean Up			
large aquarium			
pitcher of water			

Foam Peanuts

Learning Objectives: *Students learn about the impact of packing materials on the environment.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Solutions and Mixtures
Chemical Reactions
Environmental Chemistry

PROCESS SKILLS

Describing/Defining
Classifying
Controlling Variables

GROUP SIZE

1–3

SNEAK PEAK inside …

ACTIVITY

Students observe changes when they add water and iodine to Styrofoam and biodegradable packing peanuts.

STUDENT SUPPLIES

see next page for more supplies

tincture of iodine
Styrofoam peanuts
biodegradable foam peanuts
popcorn
spoons and plastic cups, etc.…

ADVANCE PREPARATION

see next page for more details

Make iodine and water solution
Pop the popcorn, etc.…

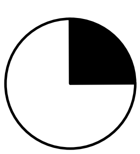
OPTIONAL EXTRAS

DEMONSTRATION
Dissolving Styrofoam in Acetone (p. D - 18)

EXTENSIONS
Iodine Starch Test (p. D - 22)
Compost in a Bottle (p. D - 23)

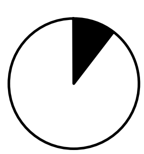
TIME REQUIRED

Advance Preparation



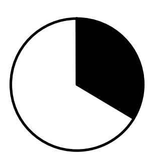
15 minutes

Set Up



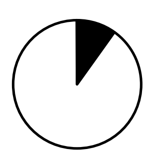
5 minutes

Activity



20 minutes

Clean Up



5 minutes

SUPPLIES

Item	Amount Needed
tincture of iodine	1–2 teaspoons per class
Styrofoam packing peanuts	1–2 per group
biodegradable packing peanuts (e.g., Biofoam™)	1–2 per group
microwaveable popcorn (or other starch source, e.g., white bread or plain crackers)	1 package per class
pop-top squeeze bottles (e.g., water or sports drink) 16 oz. or larger	2 per group
water	1 cup per group
spoons (e.g., teaspoon measures)	1 per group
clear plastic cups	3 per group
wooden craft sticks	3 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Popcorn:
- Pop the popcorn and let it cool.

Water:
- Fill pop-top squeeze bottles with water.
- Label the bottles "water."

Iodine Solution:
- Add 1 teaspoon of tincture of iodine to 2 cups of water.
- Fill pop-top squeeze bottles with about ¼ cup of iodine solution.
- Label the bottles "iodine solution."

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

Notes and Hints
- In place of popcorn, bread or plain crackers will work. Popcorn, bread, and plain crackers give the most noticeable color change and are structurally the most similar to the biodegradable foam peanut.

SETUP

For each group

- iodine solution in pop-top squeeze bottle
- water in pop-top squeeze bottle
- 1–2 Styrofoam peanuts
- 1–2 biodegradable foam peanuts
- 1–2 pieces of popped popcorn
- 3 wooden craft sticks
- 3 clear plastic cups
- spoon

At a central location (or with the teacher)

- towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided primarily for the teacher's benefit.

Choose questions that are appropriate for your classroom.

Not all packing peanuts are made from the same ingredients. Students will examine the different types of packing peanuts and decide which kind is better for the environment.

What happens to your trash after you throw it away?
Students might say that the garbage man takes it, it goes to the landfill, sits there, some stuff decomposes.

Does all of our trash break down or decompose the same?
No; some waste, such as plant or yard waste, decomposes rather quickly. Other waste, such as plastic and Styrofoam can take 100 years to break down!

Have you ever gotten a package in the mail, and the box is full of little foam peanuts to keep the object in the box safe?
Yes! No. Maybe….

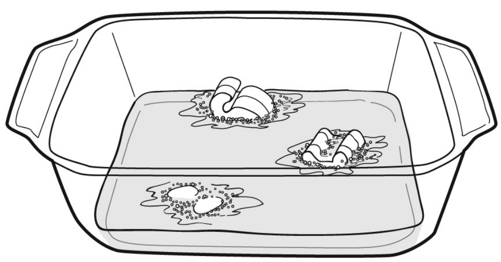
Those peanuts come in two different forms. Some are made of Styrofoam, which is made from plastic, while others are made from corn starch. We are going to look at how the different types of packaging peanuts affect the environment differently.

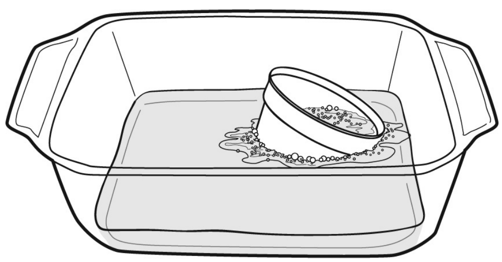
Dissolving Styrofoam

This demonstration is best done at the end of the activity. Show students what it takes to dissolve the Styrofoam peanuts.

Supplies

- acetone (available in most hardware stores)
- Styrofoam cup or leftover Styrofoam peanuts from each group
- shallow glass dish, cup, or jar (at least as large in diameter as the Styrofoam cup, if used)





Demonstration

- In the shallow dish, cup, or jar, pour a small amount of acetone. Drop dry Styrofoam peanuts (water interferes with the reaction) into the acetone. All the Styrofoam will quickly dissolve in the acetone.
- For a more dramatic demonstration, place a small Styrofoam cup into the acetone. It will quickly dissolve.

Explanation

Styrofoam is not biodegradable, but it does dissolve with acetone. Actually, to be more precise, the acetone collapses the physical structure of the Styrofoam, releasing all of the air bubbles trapped within (they can be seen escaping as the Styrofoam dissolves). After the acetone evaporates, there is a small amount of liquid polystyrene left in the dish.

CAUTION: Acetone is flammable and poisonous. Keep away from heat and open flames.

Safety and Disposal

- Filter and collect the used acetone for reuse.
- Solid waste may go in the trash.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page D - 26, working in groups of 1–3. Below are suggestions to help the teacher facilitate the activity.

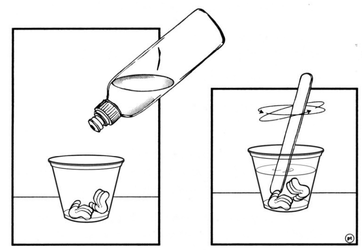
NOTES

Foam Peanuts

SCIENTIFIC PROCEDURE

This handout is on p. D - 26.

1. Label three cups "Styrofoam," "Biofoam," and "Popcorn."
2. Put one or two pieces of each material in its corresponding cup.
3. Add three spoonfuls of water to each cup. Stir with a wooden stick.
   - What happens to the Styrofoam?
   - What happens to the Biofoam?
   - What happens to the popcorn?



Running Suggestions

- ❑ You may decide to set up the lab with the Styrofoam, biofoam, and popcorn at a central location. Students can collect their own materials.

Ongoing Assessment

- ❑ How are the different packing materials similar? How are they different?
- ❑ Why do you think iodine changes color with popcorn and with the biodegradable foam? *(They both contain something similar that reacts with the iodine [starch].)*

Safety and Disposal

- ❑ All materials may go in trash. If possible, rinse the Styrofoam peanuts off and reuse for another class.

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

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Students learned how different substances used for the same purpose can affect the environment in very different ways.

What happened when you put water on the popcorn? On the biofoam? On the Styrofoam?
The popcorn dissolved in the water. The biofoam dissolved in the water. Styrofoam didn't dissolve in the water.

Based on how it reacted with water, is the biodegradable foam more similar to the popcorn or to the Styrofoam? Why do you think so?
The popcorn, because the popcorn got mushy in water, just like the biodegradable foam.

What happened when you put iodine on the popcorn? On the biofoam? On the Styrofoam?
Iodine turns dark bluish-purple with popcorn and biofoam. This indicates that biodegradable foam peanuts are made of starch, like the popcorn. Iodine stays yellowish or amber on Styrofoam.

Because the popcorn and biofoam both reacted the same to iodine, we know they must both contain the same ingredient.

Has anyone heard of starch or know what it is?
Starch is a molecule that plants use to store energy. Some common places starch can be found is in foods like pasta, potatoes, corn, rice, and wheat.

Do you think it is better to use Styrofoam peanuts or the starch peanuts? Why?
Starch peanuts are better. Styrofoam will not biodegrade. It remains in the environment for decades. Only harsh chemicals will deflate it. The biodegradable packing foam is starch based and will degrade when exposed to water and is not harmful to the environment.

Can biodegradable foam be a substitute for all the uses of Styrofoam?
Biodegradable foam cannot substitute for Styrofoam in all cases; for example, it would never work as a coffee cup.

Now would be an appropriate time to do the Teacher Demonstration showing how Styrofoam can be dissolved with acetone.

EXPLANATION

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

When products are mailed or sold in stores, they are wrapped in some kind of packaging. This packaging is useful to keep the product intact but can be harmful to the environment.

BACKGROUND FOR ALL GRADES

Packing and the Environment

When we buy products, we usually don't want the packaging. Depending on what the packaging is made of, it can sometimes be **recycled** and used for another purpose. If the packaging cannot be recycled, then it is trash. When trash is thrown away, it is taken to a **landfill** or other storage facility. If trash can **biodegrade**, or break down by natural processes, it eventually becomes soil. Eventually, non biodegradable trash accumulates in the landfill and can pollute the environment.

Styrofoam versus Biofoam

Styrofoam and **biodegradable foam** (Biofoam) are both made of air bubbles trapped inside a solid. This makes the foams lightweight and good for cushioning and for insulating. For this reason, they are used in packaging to protect materials from damage.

When biodegradable foam is exposed to water, it **dissolves** and washes away. It does not accumulate to pollute the environment. In contrast, Styrofoam does not dissolve in water and can last in landfills for over a hundred years or more.

Styrofoam can be dissolved by various materials. However, these are usually irritating, flammable chemicals such as acetone or paint thinner. These chemicals deflate the Styrofoam and release the trapped air. Although it takes up less space, the deflated Styrofoam is still present. Also, the chemicals used to dissolve the Styrofoam are harmful to the environment.

Iodine

Iodine can be used to test for starch. Iodine is normally a yellowish-amber color. When iodine combines with starch, it turns dark purple.

EXTRA INFORMATION FOR OLDER STUDENTS

Styrofoam and Biofoam Polymers

Both Styrofoam and Biofoam are made from very long molecules known as **polymers**. Polymers are made of repeating smaller units.

Styrofoam molecules are made from smaller units of styrene, and long chains are known as **polystyrene** plastic (see Figure 1). This plastic is designated for recyling with the number 6 surrounded in arrows.

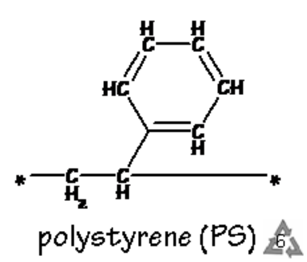


Figure 1 Molecules of styrene connect together at the stars to form long chains of polystyrene molecules.

Biofoam molecules are made from smaller units of sugar, and long chains are known as **starch**. Plants store energy in the form of starch. Starch is a major component of potatoes, pasta, bread, grains, cereal, and other foods (see Figure 2).

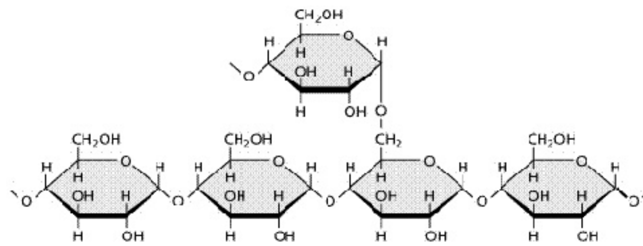


Figure 2. Each sugar molecule is a ring of carbons with hydrogen and oxygen extending off of it. Many sugar molecules (networks of 100's) link together to form starch.

Starch-Iodine Reaction

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 (I_2) molecules enter the center of the helix, where they bind to the starch to form a dark blue complex.

EXTENSIONS

Extension A: Iodine Starch Test

Use the iodine solution to find other items that contain starch.

Extra Supplies

- other starch sources (e.g., crackers, pasta, bread, potatoes, paper towels)—1–2 pieces per group
- non-starch sources (e.g., cheese, apples, plastic, sponge, leaves)—1–2 pieces per group
- iodine solution from main activity

Extra Instructions

- Provide an assortment of items for students to test with iodine solution.
- Younger students can sort the items as those containing starch or not containing starch as a simple data table.
- Older students should create a data table to list items that contain starch and those that do not.

Explanation

Iodine solution turns blue in the presence of starch. Items that contain starch should show a blue or dark stain from the iodine.

Extension B: Compost in a Bottle

- 2-liter plastic bottle— per group
- soil—2 cups per group
- trash items (e.g., food scraps, Styrofoam, biodegradable packing foam, grass, paper, plastic, foil)—1 cup per group
- water
- scissors—1 pair per group
- tape—roll per group

Extra Instructions

- Cut the 2-liter bottle in half horizontally. Cut air holes in the top section of the bottle.
- Fill the bottom half of the bottle with a layer of soil, a layer of trash, and a layer of soil.
- Slip the top half of the bottle back onto the bottom half. Tape the bottle halves together.
- Add some water ("rain") from the top.
- Store the bottle in a warm place for at least a month. Add a little water daily.
- Record observations. Which things break down, or are biodegradable?

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES

Waste Management

Students can track their usage of materials for a week. They can categorize their materials by whether the items they use can be recycled or reused. Have students compare their material usage and trash accumulation to other Americans, and to other countries.

Landfill Structure

Research how landfills are built and how extra precautions are made to keep trash and toxins from entering the environment. Does landfill structure promote or delay decomposition? For instance, students might research whether or not food decomposes in landfills.

ART

Foam Sculptures

Let the students build structures by wetting an edge of one biodegradable-foam packing peanut with a few drops of water. The drops of water create a sticky surface on the foam. The sticky surface of a foam piece will stick to paper, cardboard, or another piece of biodegradable packing foam. Structures can be built from these pieces.

ENGINEERING

Potato Chip Mailer

Give students a large envelope, a potato chip, and various packaging materials (cotton balls, egg cartons, Styrofoam, Biofoam, popcorn, newspaper, plastic bags, tape). Their goal is to design a package that will keep the potato chip from breaking during transit. Mail the packages through the U.S. Postal Service to the school. When you receive the packages, students should evaluate which methods were best in various categories: chip protection, environmental impact, artistic impression, minimal materials use, reusability.

RESOURCES

Web – http://www.worldwise.com/biodegradable.html
Even though things are biodegradable, they may not break down in a landfill. Since a landfill has many layers, air and water cannot get to all items to help them break down. This site discusses this issue and includes a table of the degradation times of common materials.

Web – http://www.worldcentric.org/store/bioplastics.htm
Styrofoam and most plastics are made from petrochemicals (oil and gas). Bioplastics are created from plant materials, a potentially renewable resource. They are more likely to break down than traditional plastic, depending upon landfill conditions.

Showers, Paul, *Where Does the Garbage Go?*, Harper Trophy Publishing
Reading level: kindergarten to 3rd grade
Clearly written and accessible to young children, the book explains what happens to solid waste, what goes into landfills, and how aluminum, newspapers, glass bottles and jars, and plastics are recycled today.

Gibbons, Gail, *Recycle! A Handbook for Kids*, Little, Brown Young Readers
Reading level: 2nd to 5th grade
A very readable and well-organized offering that's filled with information. Gibbons' cartoons in primary shapes and colors graphically illustrate the contents of a landfill and how to recycle various products to cut down on the need for landfills—which in some areas are in short supply. Discussing paper, plastic, glass, cans, and polystyrene, the author describes how and why to recycle, as well as the benefits of recycling.

VOCABULARY

biodegradable foam: a form of packaging material made of starch that has been filled with many bubbles of air; primarily used for protecting materials during shipping

biodegrade: to break down by natural processes

dissolve: when the molecules of a substance become completely surrounded by the molecules of another substance

landfill: location designated to collect trash

polymer: a large molecule made up of many repeated molecules

polystyrene: a polymer made of styrene molecules; this plastic is mainly used for cups and food containers

recycle: use again; break down products into their component parts and remake into the same or different product

starch: a polymer made of sugar molecules; plants create this molecule as a way to store energy

Styrofoam: brand name for polystyrene plastic that has been filled with many bubbles of air; primarily used for protecting materials during shipping

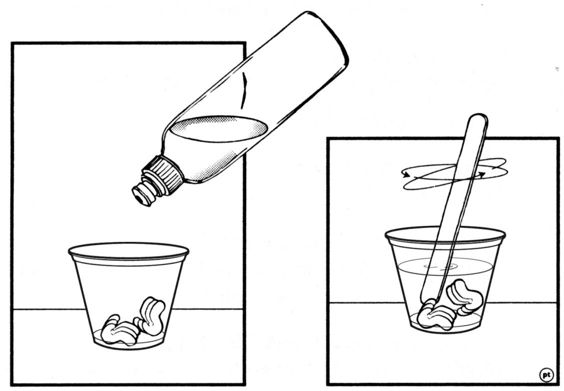
Foam Peanuts

SCIENTIFIC PROCEDURE

1. Label three cups "Styrofoam," "Biofoam," and "Popcorn."

2. Put one or two pieces of each material in its corresponding cup.

3. Add three spoonfuls of water to each cup.
   Stir with a wooden stick.
   - What happens to the Styrofoam?

   - What happens to the Biofoam?

   - What happens to the popcorn?

4. Add half a spoonful of iodine solution to each cup.
   Stir with a wooden stick.
   - What happens in the Styrofoam cup?

   - What happens in the Biofoam cup?

   - What happens in the popcorn cup?

5. Clean up your area
   - Follow your teacher's directions.

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Foam Peanuts

Recommended group size: 1–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
tincture of iodine	1–2 teaspoons per class		
Styrofoam packing peanuts	1–2 per group		
biodegradable packing peanuts (e.g. Biofoam™)	1–2 per group		
microwaveable popcorn (or other starch source)	1 package per class		
pop-top squeeze bottles (e.g., water or sports drink)	2 per group		
water	1 cup per group		
large spoons (e.g., tablespoons)	1 per group		
small spoons (e.g., teaspoon measures)	1 per group		
clear plastic cups	3 per group		
wooden craft sticks	3 per group		
Extension A			
other starch sources (e.g., crackers, pasta, bread, potatoes, paper towels)	1–2 pieces each item per group		
non starch sources (e.g., cheese, apples, plastic, sponge, leaves)	1–2 pieces each item per group		
Extension B			
2-liter plastic bottle	1 per group		
soil	2 cups per group		
trash items (e.g., food scraps, Styrofoam, biodegradable packing foam, grass and leaves, paper, plastic, foil)	1 cup per group		
water	a little each day		
scissors	1 pair per group		
tape	1 roll per group		

Supply Worksheet continues on next page.

Teacher Demonstration			
acetone (available in most hardware stores)	approximately 1 cup		
Styrofoam cup or leftover Styrofoam peanuts from each group	a few pieces		
shallow glass dish, cup, or jar (at least as large in diameter as the Styrofoam cup, if used)	1 per class		
waste container for used acetone, with lid	2 cup capacity		
funnel	1 per class		
coffee filter	1 per class		

Pollution Diffusion

Learning Objectives: *Students identify some factors affecting how chemicals spread out into new areas. Students gain experience in scientific investigation.*

GRADE LEVEL

5–8

SCIENCE TOPICS

Solutions and Mixtures
Techniques
Environmental and Geochemistry

PROCESS SKILLS

Making Models
Hypothesizing
Analyzing
Controlling Variables

GROUP SIZE

2–4

SNEAK PEAK inside …

ACTIVITY

Students bury M&M's™ in "soils," like rice, sand, flour, etc., and add water. The M&M's colors diffuse through different soils at different rates, just like leaking underground tanks.

STUDENT SUPPLIES

see next page for more supplies

flat plastic lids
burying material, sand, flour, rice
M&M's

ADVANCE PREPARATION

see next page for more details

Gather plastic lids in advance
Set out sand, rice, etc.…

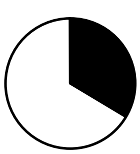
OPTIONAL EXTRAS

DEMONSTRATION
Diffusion in Water (p. D - 33)
Randomness of Diffusion (p. D - 33)

EXTENSIONS
Inquiry Opportunity: Further Questions (p. D - 39)
Inquiry Opportunity: Build a Better Tank (p. D - 39)

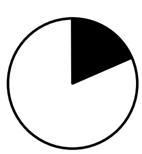
TIME REQUIRED

Advance Preparation



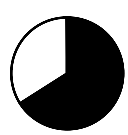
20 minutes

Set Up



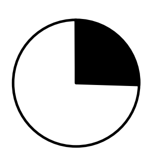
10 minutes

Activity



40 minutes

Clean Up



15 minutes

SUPPLIES

Item	Amount Needed
flat plastic lids, 4–6 inches in diameter (from oatmeal tubs, yogurt containers, peanut butter jars, mayonnaise jars, and butter tubs)	4 per group
water	1–2 cups per group
plastic pop-top squeeze bottles, 12 oz. or larger	1 per group
M&M's™	1 pound per class
flour (corn starch also works)	½ cup per group
rice	½ cup per group
sand	½ cup per group
plastic cups, 8 oz.	3 per group
plastic spoons or teaspoons	2 per group
various measuring cups, beakers, or graduated cylinders	several for class to share
Diffusion Measuring Tools (see p. D - 46)	1 per class
transparency sheets (optional)	1 per group
ruler (optional)	1 per group
watch or view of the classroom clock	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Plastic Lids:

- For a few weeks before the activity, encourage students to bring in large, flat plastic lids.
- Deeper lids from jars work better to bury the M&M's.
- Sort the lids so that each group will have 4 lids of a similar size.

Water:

- Fill the plastic pop-top squeeze bottles mostly full of water.
- Label these bottles "water."

Burying Materials:

- Fill plastic cups separately with ½ cup each of sand, rice, and flour.
- Label these cups with their contents.

Diffusion Measuring Tools:

- Photocopy the Diffusion Measuring Tools on p D - 46 onto transparency plastic. If transparency plastic is not available, regular paper will work.
- Cut out the Diffusion Measuring Tools for students to use during the activity.
- If using plastic, each group needs one measuring tool. If using paper, supply each group with 4 measuring tools since they may get wet.

Notes and Hints

- Students should have prior experience with scientific investigations. They should understand why it is important to control variables in an investigation. They should also know how to control variables.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by other items in the lab.

SETUP

For each group

- sand, rice, and flour in plastic cups
- pop-top squeeze bottle filled with water
- plastic lids (4 per group)
- plastic spoons and teaspoons
- Diffusion Measuring Tool (1 if plastic, 4 if paper) or ruler
- watch or view of the classroom clock

At a central location (or with the teacher)

- sponges and towels for clean up
- measuring cups, beakers, graduated cylinders
- M&M's

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students use the topic of groundwater pollution to design and conduct a scientific investigation.

Use time before the activity to help students think about the experimental design of the investigation.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

What happens to all the water that falls from rain? Does it just stay in puddles forever?
The water seeps into the ground or runs along the surface. Eventually it collects in rivers, reservoirs, lakes, etc. Not all water goes to the ocean immediately; some may soak into the soil and get trapped underground. It is called "groundwater."

What is groundwater? Why is it important?
Rainwater that soaks into the soil becomes groundwater. People can drill wells to use groundwater as drinking water. Groundwater underneath hills or mountains can leak out the edges as natural springs.

What would happen if groundwater became polluted?
Drinking water in wells would become polluted. Also, since groundwater does move underground, it could eventually move to rivers and streams and carry pollution there. Organisms (such as the bacteria that help plants grow) that live in groundwater could be harmed.

In this investigation we are going to study a Leaking Underground Storage Tank (LUST). We want to know what effect the surrounding material has on the diffusion of pollutants. We will use M&M's as the leaking underground storage tank. We will set up four different trials and surround the M&M's with different materials: water, sand, rice, and flour. In each case, we will use water to make the color of the M&M's diffuse into the different "soil."

But there is a problem. Just like real life, there are many parts to this experiment: the color of the candies, the depth of the soil, the type of soil, the amount of water, etc.

If we want to measure ONLY the effect of the type of soil on how fast the candy colors will diffuse, then what are some variables we need to control, or "hold constant"?
To "control" or "hold constant" a variable means to keep it the same from experiment to experiment. The only variable that should change from experiment to experiment is the type of soil. Encourage students to list as

many variables as possible, including how deep to bury the candies, how much water to add, how to add the water (at the center or edges, all at once?), what color of M&M to use, what temperature of water, where to place the M&M's (center or edges?), …and on and on.

Ideally, students will become aware of the complex environment they are controlling and create an experimental protocol that they record and strictly follow. You can either decide as a class how to set up the experiment, or allow student groups to discuss and decide for themselves.

How shall we measure the diffusion of our M&M candy coat?
Students can use the Diffusion Measuring Tools (p. D – 46) transparencies if they like or devise another method (e.g., rulers) to measure the diffusion.

TEACHER DEMONSTRATION

Diffusion in Pure Water
This demonstration mimics the actual activity, except that the M&M's are placed a flat plastic lid filled with pure water with no soil. This allows students to see the diffusion of the candy color more easily.

Supplies
- flat yogurt lid or transparent Petri dish (if transparent, it can be shown on an overhead projector)
- M&M's of different colors
- water

Demonstration
- Fill the lid or Petri dish with enough water to just cover an M&M.
- Place the M&M in the water. Observe.

Explanation

This demonstration shows diffusion most clearly and helps students visualize the effect they will be measuring in their own investigations.

Randomness of Diffusion

In this demonstration, objects represent molecules. Using a random process, the objects diffuse from being together in one location and become scattered.

Supplies
- 10 pennies and an overhead projector
  OR
- 10 sticky notes and the board
- 1 die (standard 6-sided, or can use 4-sided or 8-sided)

Demonstration

- Start with 10 pennies in a stack on the overhead projector. Alternatively, start with a stack of 10 sticky notes in one location of the board. Explain that these objects represent a group of molecules in one location.
- For each object, roll a die. Depending on the roll of the die, do one of the following:
  1 Move object left
  2 Move object down
  3 Move object right
  4 Move object up
  5 No movement
  6 No movement

  This will create four new stacks surrounding the spot where the original was. You can use a 4-sided die to avoid the confusion on rolls of 5 or 6. Or you can use an 8-sided die and move the objects in diagonals as well.
- Repeat the die rolls and movements for each of the newly created stacks. This will diffuse the objects farther. Some objects may return to the starting location. This will create new stacks of objects.
- At this point, you will have many stacks of pennies or sticky notes. Continue to roll the die and diffuse the objects from their stacks until they appear randomly scattered.

Explanation

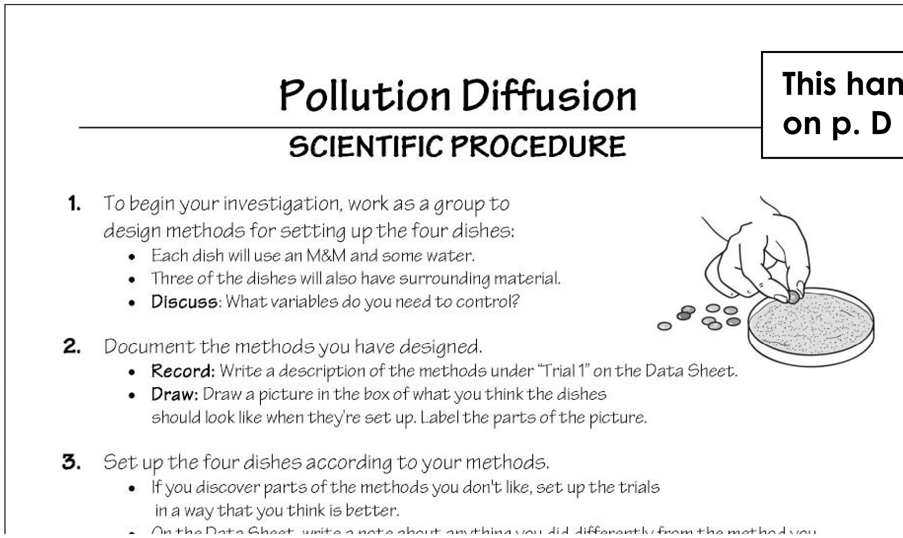
Each penny or sticky note represents one molecule. As molecules diffuse, they move in a random way through surrounding material. From this random movement, molecules change from being closely packed in one location to being spread out throughout the substance.

> **MISCONCEPTION ALERT:** The diffusion of actual pollution through water in soil may not be completely random due to several factors. Rocks and clays could get in the way of the diffusing water. Gravity can also play a role.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page D - 42, working in groups of 2–4. Below are suggestions to help the teacher facilitate the activity.

NOTES



Pollution Diffusion

SCIENTIFIC PROCEDURE

1. To begin your investigation, work as a group to design methods for setting up the four dishes:
   - Each dish will use an M&M and some water.
   - Three of the dishes will also have surrounding material.
   - **Discuss**: What variables do you need to control?
2. Document the methods you have designed.
   - **Record:** Write a description of the methods under "Trial 1" on the Data Sheet.
   - **Draw:** Draw a picture in the box of what you think the dishes should look like when they're set up. Label the parts of the picture.
3. Set up the four dishes according to your methods.
   - If you discover parts of the methods you don't like, set up the trials in a way that you think is better.
   - On the Data Sheet, write a note about anything you did differently from the method you

This handout is on p. D - 42.

This activity lets students design a complex investigation. Students will be burying M&M's candies in different substances, adding water, and watching the colored coating diffuse away from the candy.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

To measure their results, students can use the concentric circle lines on the "Diffusion Measuring Tools" transparencies (see Advance Preparation) to measure the plume of the diffusion.

Running Suggestions

- Introduce the activity by making sure students understand the necessity of controlling variables. Students should change just <u>one</u> variable, the material surrounding the M&M's. All other variables should remain unchanged: the location of the M&M's, the amount of water added, the color of the M&M's, the amount of material surrounding the M&M's, the method of adding the water, the order that ingredients are added, the time the diffusion is allowed to happen, etc.
- Students should have the choice to define the fixed factors. They will come up with a variety of methods to study the diffusion of the M&M's. All scientifically sound methods are acceptable.
- If students are less interested in varying the type of soil, encourage them to try other variables instead, such as temperature of the water or the color of the M&M's.

Ongoing Assessment

- Ask students to evaluate their procedure design. Are there problems with their design? How are they measuring the diffusion of the candy pollution? Are they holding all variables constant except for one?
- Encourage students to complete two trials of the experiment. After one trial, students are likely to see refinements they can make to their design. Adjusting their methods will allow students to fully experience the scientific process.
- Find out what questions students wish to investigate next. Keep a record of these questions on a notepad or on the board. Through Extension A, students should design their own experiments to explore these questions.

Safety and Disposal Information

- All used materials may be disposed of in the trash.

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

You may want to survey the class to find what methods students used to set up the experiment. Find similarities and differences in the procedures students used. Then look at the data collected to see if different methods affected the results.

What trends do you notice?
For most students, the diffusion in the rice will be fastest and the diffusion in the sand will be slowest.

Are there any data that don't seem to match the rest? Where did these data come from?
Try to determine if the methods students used account for the exceptions.

Are there any conclusions we can draw from this data?
Answers will vary.

What investigation should we do next? What questions should we try to answer?
Students may come up with many possible questions. Write these down for use in Extension A.

Generating new questions is an essential part of the scientific process. At the conclusion of an experiment, scientists often find that there are many new ideas to explore.

EXPLANATION

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

This activity uses the current issue of leaking underground storage tanks as an opportunity for students to practice their inquiry skills. To do so, students bury M&M's in a type of "soil" (rice, sand, flour, etc.), add water, and watch as the candy color diffuses away from the M&M's over time. The rate of diffusion depends on the type of soil.

The Scientific Procedure sheet is deliberately vague to encourage student creativity as they design their investigation and decide which variables they must control as they measure the effect of different soils.

If students would like to change other variables (e.g., water temperature, color of M&M's, depth of burying, etc.), they can.

> For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

The Importance of Groundwater

Groundwater starts as surface water, including rainwater, meltwater from snow and ice, and water from lakes, streams, and rivers. Gravity pulls much of this water down into the ground through holes and spaces in the rock, sand, and soil. This process can take years depending on how **permeable** (allows water to pass through) the surface soil is. The soil filters and cleans the water as it moves down through the layers. Eventually, this water collects in the holes of **porous** rock. About 60% of the available fresh water on Earth is held in groundwater. Currently, about half of the U.S. population gets its drinking water from groundwater.

> For a detailed description of how pollutants travel through the ground, see the Explanation section in **Cleaning with Dirt**.

Sediment or rock in which water is stored and can flow through is called an **aquifer**. To access the groundwater, people drill wells down to the aquifer layer. Water can flow from one hole through the entire aquifer. This means if **pollution** gets into one part of the aquifer, the entire aquifer—and people's drinking water—can become contaminated.

Leaking Underground Storage Tanks

An **underground storage tank** (**UST**) is a buried container to hold something. For example, gas stations use USTs to store gasoline. Each gasoline station has two to four tanks, and each tank is 4,000 to 12,000 gallons in size. This is the size of one large truck trailer. USTs are also used in homes and other buildings: septic tanks, buried radioactive waste, and oil tanks.

The walls of underground storage tanks can **corrode** and rust over time, allowing the contents to leak. Groundwater, if it is present, speeds up the corrosion. When a UST leaks, it is called a **leaking underground storage tank** (**LUST**). Usually, the leaking chemical spills out of the tank in a particular direction (called a **plume)** and contaminates groundwater. This type of pollution is called **point source pollution** because the contamination can be traced to one single location.

Leaking underground storage tanks aren't the only sources that pollute groundwater. Landfill seepage, animal waste, fertilizers, pesticides, industrial waste, road salt, and fuel spills all contribute to the contamination of groundwater. These sources are known as **non-point source pollution**, since the pollution may come from multiple sources.

A Pollution Model

For this activity, students use an M&M's candy to represent a LUST. When students add water to their model, they will see the color from the candy dissolve and **diffuse** (spread out) through the water.

Each surrounding material (flour, sand, rice) affects the diffusion of color to a different extent. This means that the "pollution" diffuses differently in each of these substances.

Soil	Flour	Sand	Rice
Open spaces between particles	Smallest	Medium	Largest
Rate of diffusion	Slowest	Medium	Fastest

Rice has the most open spaces between grains and will usually allow the fastest diffusion. However, it will absorb water over time, swell, and allow slower diffusion. Flour has the smallest spaces between particles and usually allows the slowest diffusion. In addition, it also absorbs water, swells, and the space between particles is reduced. Sand is not absorbent and has a medium particle size, so it allows a medium rate of diffusion.

Experimental Design
In this activity, students have an opportunity to design their own experiment. They are given a question to answer and need to design an experiment to answer that question. There are many **variables** to consider in this model, that is, many things that can change. This requires a lot of careful thought about how to **control** (hold constant) these variables, or keep all of the factors the same in the experiment except the one they are testing. The more students practice with identifying variables and learning to control them the better they will become at practicing science.

EXTENSIONS

Extension A: Inquiry Opportunity—Further Questions
Use questions that have arisen in the original investigation to frame a new experiment. Material needs will vary depending on the question asked. Ideas might include changing various variables, such as the color of the M&M's, the depth at which they are buried, the composition of the soil mixture, the temperature of the water, or the use of alternative liquids.

Extension B: Inquiry Opportunity—Build a Better Tank
Are some storage tanks better than others? Are there ways to prevent a tank from leaking? Are there ways to bury a tank that minimizes the damage from leakage? Students can try different pollution sources (other candies), they can try various coatings on the tank (nail polish, candle wax, etc.), and they can try burying the tank in different materials (gravel, shredded paper, etc.).

Extra Supplies
- ❑ alternative pollution sources (Skittles, Lifesavers)
- ❑ tank coating materials (nail polish, plastic wrap, candle wax)
- ❑ alternative burying materials (Styrofoam, gravel, shredded paper)
- ❑ other materials as suggested by students

CROSS-CURRICULAR CONNECTIONS

LANGUAGE ARTS **Activism**
Have students write letters to government officials about LUSTs. Write letters to presidents of corporations that use LUSTs.

SOCIAL STUDIES **Hanford Nuclear Facility**
Research the history of the Hanford nuclear facility in Washington State. Read about current clean up efforts.

MATHEMATICS **Diffusion Graphs**

Record the distance of the plume at different time intervals during the diffusion experiment. Create a time distance graph to show the different rates of diffusion in different experiments.

GEOGRAPHY **Make a Tank Map**

Use one of the links listed in the resources to find a list of leaking underground storage tanks in your city, county, or zip code. Mark these locations on a map.

RESOURCES

Web – http://www.epa.gov/safewater/kids/wsb/

The United States Environmental Protection Agency maintains a website with information and educational activities. The Water Sourcebooks contain 324 activities for grades K–12. The chapters labeled "Ground Water Resources" have activities and information relevant to this activity.

Web – http://www.hanford.gov/orp/

The Hanford Site—Office of River Protection. Closing the nuclear waste tanks to protect the Columbia River.

Web – http://www.deq.state.or.us/wmc/tank/lustlist.htm

Oregon Department of Environmental Quality lists 500 pages of sites for leaking underground storage tanks. County, street address, city, dates of cleanup are listed.

Web – http://www.ecy.wa.gov/programs/tcp/ust-lust/tanks.html

Washington State Department of Ecology maintains a list of LUST sites. Sorted by county, the 600-page list contains city, latitude, longitude, and cleanup status of storage tanks.

Web – http://www.deq.state.id.us/waste/prog_issues/ust_lust/index.cfm

Idaho Department of Environmental Quality has two lists of LUST and UST sites. Lists have city, zip code, and clean-up status listed.

Kramer, Stephen P., *How to Think Like a Scientist: Answering Questions by the Scientific Method*

Reading level: 4th to 7th grade

Humorous and appealing pictures accompany explanations of how to use the scientific method to answer questions. Also points out the problems encountered when the scientific method is not followed correctly.

Blanford, Millie and Camplair, Patience, *Teaching The Scientific Method: Instructional Strategies To Boost Student Understanding*

The lessons in this book enable students to solve problems using the scientific method, conduct research, use scientific equipment appropriately, construct and explain tables, graphs, and reports, and develop experiments independently.

VOCABULARY

aquifer: sediment or rock in which water is stored and can flow through

control: to keep a factor the same in a scientific experiment; also called "hold constant"

corrode: to slowly weaken or decay, often due to chemical reactions

diffuse: to spread out and disperse

groundwater: water that is held underground

leaking underground storage tank (LUST): a buried container that has broken and started to leak its contents

non-point source pollution: pollution that accumulates from multiple sources

permeable: allows another substance to pass through

plume: an area where a contaminant has spread out

point source pollution: pollution that can be traced to a specific source

pollution: potentially harmful contamination of a resource

porous: having open spaces between particles in a material

underground storage tank (UST): buried container that holds some substance

variable: a changeable factor in a scientific experiment

Pollution Diffusion

SCIENTIFIC PROCEDURE

1. To begin your investigation, work as a group to design methods for setting up the four dishes:

- Each dish will use an M&M and some water.
- Three of the dishes will also have surrounding material.
- **Discuss**: What variables do you need to control?

2. Document the methods you have designed.

- **Record:** Write a description of the methods under "Trial 1" on the Data Sheet.
- **Draw:** Draw a picture in the box of what you think the dishes should look like when they're set up. Label the parts of the picture.

3. Set up the four dishes according to your methods.

- If you discover parts of the methods you don't like, set up the trials in a way that you think is better.
- On the Data Sheet, write a note about anything you did differently from the method you originally designed. *(Don't erase or cross out the old method though.)*

4. When you're finished setting up, allow the four trails to run.

- Observe as the color diffuses from the M&M's.
- **Record:** On the Data Sheet, write about what you observe.
- **Draw:** Draw a picture bellow of what the dishes look like as they are running. Label the parts.

Drawing for step 1	Drawing for step 3

5. For Trial 2, revise and repeat your investigation.

- You will be running a second series of the same four trials.
- **Discuss:** What problems did you encounter during the first series?
- **Discuss:** How can you improve your methods from Trial 1?

6. Document the set-up methods you have designed.

- **Record:** Write a description of the methods under "Trial 2" on the Data Sheet.
- **Draw:** Draw a picture in the box of what you think the dishes should look like when they're set up. Label the parts of the picture.

7. Follow your new set-up methods, then allow the second series of trials to run.

- Observe as the color diffuses from the M&M's.
- **Record:** On the Data Sheet, write about what you observe.
- **Draw:** Draw a picture bellow of what the dishes look like as they are running. Label the parts.

8. Clean up your area

- Follow your teacher's instructions.

Drawing for step 6	Drawing for step 7

Pollution Diffusion

DATA SHEET

Trial 1

Write down your methods for setting up the four dishes here. Each plastic dish will contain an M&M and some water. Three of the dishes will also contain a material to represent soil. The soil materials are: sand, flour, and rice. Be sure to include as part of your methods:

- The amount of each ingredients you will use
- The order you will add the ingredients to the plastic dish
- When you will start timing
- Anything else that is special about your method

	Water only	Sand and Water	Flour and Water	Rice and Water
Diffusion time (minutes)				
Distance of diffusion (cm)				

Other important observations:

Trial 2

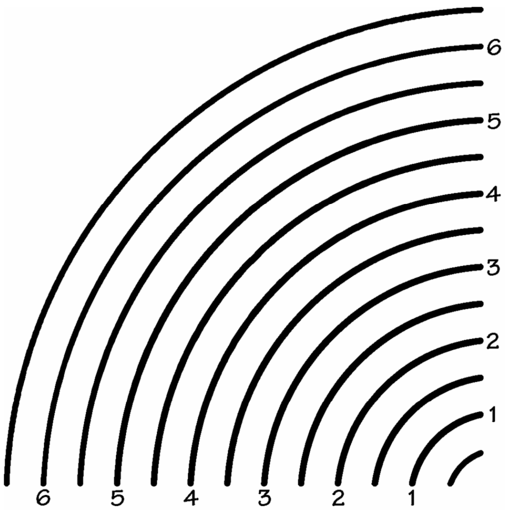
List the ways you have decided to change your set-up method. Describe the ways the set-up is different and how to follow the new method. Explain why you made the changes you did.

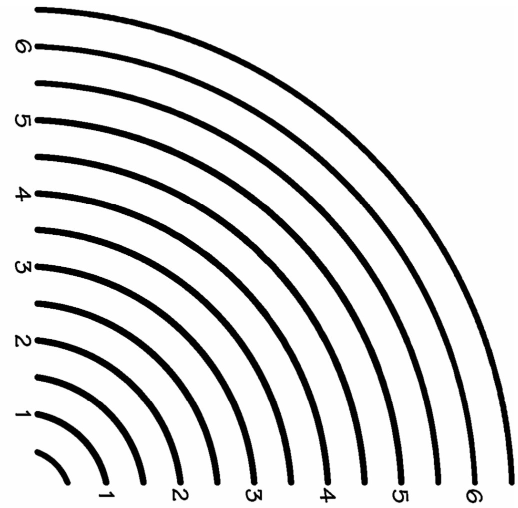
	Water only	Sand and Water	Flour and Water	Rice and Water
Diffusion time (minutes)				
Distance of diffusion (cm)				

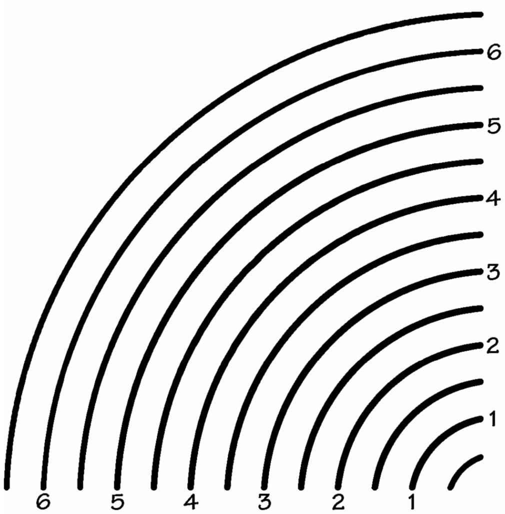
Other important observations

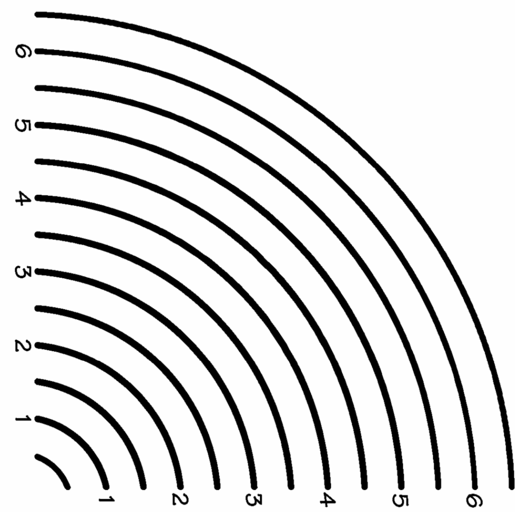
Diffusion Measuring Tools

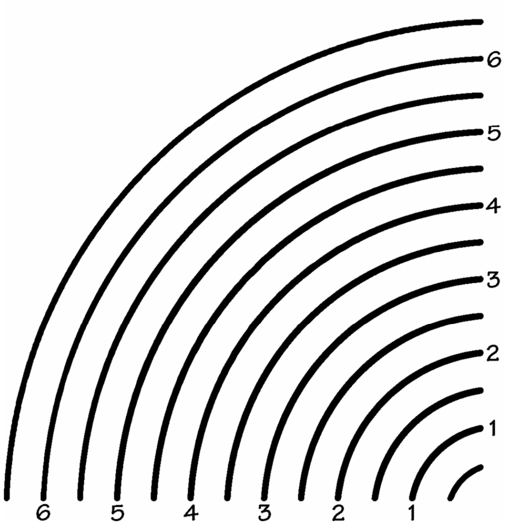
Photocopy onto plastic transparency stock. Cut out and distribute to students.

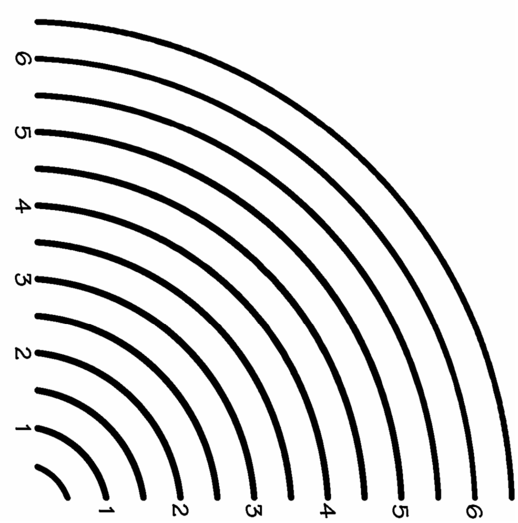












This worksheet is also available online at **www.omsi.edu/k8chemistry.**

Pollution Diffusion

Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

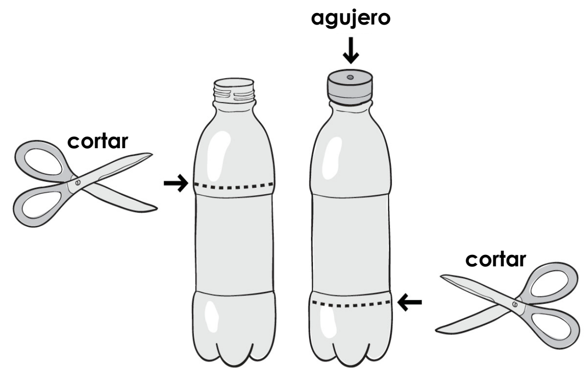
Supplies	Amount Needed	Supplies on Hand	Supplies Needed
flat plastic lids, 4–6 inches in diameter (from oatmeal tubs, yogurt containers, peanut butter jars, mayonnaise jars, and butter tubs)	4 per group		
water	1–2 cups per group		
plastic pop-top squeeze bottles, 12 oz. or larger	1 per group		
M&M's™	1 pound per class		
flour (corn starch also works)	½ cup per group		
rice	½ cup per group		
sand	½ cup per group		
plastic cups, 9 oz. or larger	3 per group		
plastic spoons or teaspoons	2 per group		
various measuring cups, beakers, or graduated cylinders	several for class to share		
sponges and towels for clean up	several for class to share		
Diffusion Measuring Tools (see p. D – 46.)	1 per class		
transparency sheets (optional)	1 per group		
ruler (optional)	1 per group		
watch or view of the classroom clock	1 per group		
Extension A			
will vary depending on questions asked			

Supply Worksheet continues on the next page.

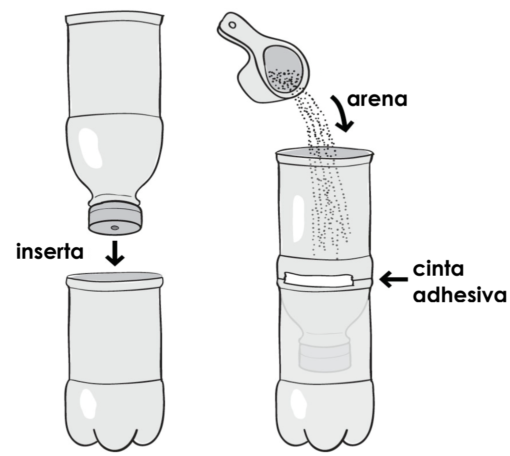
Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Extension B			
Skittles™	1 pound per class		
Lifesavers™	1 pound per class		
clear nail polish	2 bottles per class		
plastic wrap	2 packages per class		
votive candles	1 per group		
Styrofoam	½ cup per group		
gravel	½ cup per group		
Teacher Demonstration			
Diffusion in Pure Water			
transparent dish	1 for demonstration		
M&M's™	several of different colors		
water	1–2 tablespoons		
overhead projector	1 for demonstration		
Randomness of Diffusion			
pennies **OR** sticky notes	10 for demonstration		
overhead projector or the board	1 for demonstration		
1 die (standard 6-sided or can use 4-sided or 8-sided)	1 for demonstration		

Limpiando con Tierra

PROCEDIMIENTO CIENTÍFICO



1. Prepara las botellas de plástico.
    - Corta la parte inferior de una de las botellas y la parte superior de la otra.
    - Colócale la tapa con el agujero a la botella sin fondo.
2. Construye el filtro en forma de columna.
    - Inserta al revés la botella con la tapa dentro de la otra botella.
    - Une las botellas utilizando cinta adhesiva.
    - Llena la columna con arena.



3. Para preparar agua sucia mezcla agua, aceite, pintura, piedras, ramitas y polvo.
    - Escribe tu receta de agua sucia.
    - ¿Cómo se ve tu agua sucia?
4. Agrega el agua sucia en la columna y observa cómo corre el agua. Cuando el agua sucia haya llegado al fondo, agrega un vaso de agua limpia en la columna para sacar el resto de agua sucia.
    - ¿Qué ingredientes siguen estando en tu agua?
    - ¿Qué ingredientes se quedaron en la arena?
    - ¿Se filtraron algunos ingredientes más lentamente?
5. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

De Expandido a Destruido

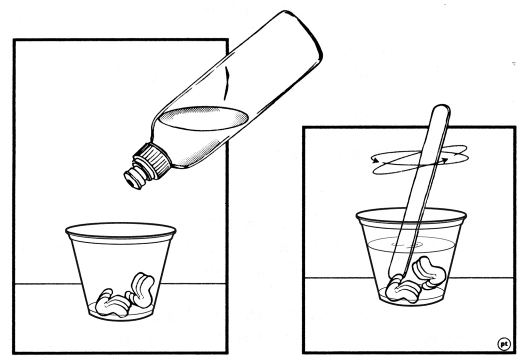
PROCEDIMIENTO CIENTÍFICO

1. Marca tres vasos con las palabras, "Goma espuma," "Goma espuma biodegradable," y "Palomitas de maíz."

2. Coloca uno o dos pedacitos de cada material en el vaso correspondiente.

3. Agrega tres cucharadas de agua en cada vaso.
   Revuelve con una paleta.

   - ¿Qué sucede con la goma espuma?
   - ¿Qué sucede con la goma espuma biodegradable?
   - ¿Qué sucede con las palomitas de maíz?



4. Agrega media cucharada de la solución de yodo en cada vaso.
   Revuelve con una paleta.

   - ¿Qué sucede con el vaso de goma espuma?
   - ¿Qué sucede con el vaso de goma espuma biodegradable?
   - ¿Qué sucede con el vaso de palomitas de maíz?

5. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Difusión de Contaminación

PROCEDIMIENTO CIENTÍFICO

1. Para empezar la investigación, trabajen como grupo para diseñar los métodos que utilizarán para preparar los cuatro platos:

- Cada plato usará un M&M y un poco de agua.
- Tres de los platos tendrán también otro material circundante.
- **Discutir**: ¿Qué variables necesitan controlar?

2. Documenten los métodos que han diseñado.

- **Registrar:** Escriban una descripción de los métodos en la "Prueba 1" de la Tabla de Datos.
- **Dibujar:** Hagan un dibujo en el recuadro de cómo piensan que deben verse los platos cuando estén listos. Marca las partes del dibujo.

3. Coloquen los cuatro platos de acuerdo a sus métodos.

- Si descubren que hay partes de sus métodos que no les gustan, coloquen las pruebas en la forma que consideren es la mejor.
- En la Tabla de Datos escriban cualquier cosa que hayan hecho diferente al método que diseñaron inicialmente. (Pero no borren ni tachen el método inicial.)

4. Cuando hayan terminado de colocar los platos, realicen las cuatro pruebas.

- Observen a medida que los colores de los M&M's se difuminan.
- **Registrar:** Escriban sus observaciones en la Tabla de Datos.
- **Dibujar:** Abajo hagan un dibujo de cómo se ven los platos a medida que realizan las pruebas. Identifiquen las partes del dibujo.

Dibujo para el paso 1	Dibujo para el paso 3

5. Para la Prueba 2, revisen y repitan su investigación.

- Realizarán una segunda ronda de las mismas cuatro pruebas.
- **Discutir**: ¿Qué problemas encontraron en la primera ronda?
- **Discutir**: ¿Cómo pueden mejorar los métodos de la Prueba1?

6. Documenten los métodos que diseñaron.

- **Registrar**: Escriban una descripción de los métodos en la "Prueba 2" en la Tabla de Datos.
- **Dibujar**: Hagan un dibujo en el recuadro de cómo piensan que deben verse los platos cuando estén listos. Identifiquen las partes del dibujo.

7. Sigan los nuevos métodos, entonces comiencen la segunda ronda de pruebas.

- Observen a medida que los colores de los M&M's se difuminan.
- **Registrar**: Escriban sus observaciones en la Tabla de Datos.
- **Dibujar**: Hagan un dibujo de cómo se ven los platos a medida que realizan las pruebas. Identifiquen las partes del dibujo.

8. Limpien su área de trabajo.

- Sigan las instrucciones de su maestro(a).

Dibujo para el paso 6	Dibujo para el paso 7

Difusión de Contaminación

HOJA DE DATOS

Prueba 1
Escriban aquí los métodos para preparar los cuatro platos. Cada plato de plástico tendrá un M&M™ y un poco de agua. Tres de los platos tendrán también un material que represente la tierra. Estos materiales son: arena, harina y arroz. Asegúrense de incluir como parte de sus métodos:

- La cantidad de cada ingrediente que utilizarán.
- El orden en que agregarán los ingredientes en el plato de plástico.
- Cuándo comenzarán a tomar el tiempo.
- Cualquier otra cosa que es especial acerca de su método.

	Sólo Agua	Arena y Agua	Harina y Agua	Arroz y Agua
Tiempo de difusión (minutos)				
Distancia de la difusión (cm.)				

Otras observaciones importantes:

Prueba 2

Escriban las maneras en que han decidido cambiar sus métodos de preparación. Describan las maneras en que la preparación es diferente y cómo seguir el nuevo método. Expliquen porqué han realizado los cambios que hicieron.

	Sólo Agua	Arena y Agua	Harina y Agua	Arroz y Agua
Tiempo de difusión (minutos)				
Distancia de la difusión (cm.)				

Otras observaciones importantes:

Concepts

Chemicals and chemical reactions are part of the environment. Some chemicals can cause environmental problems. Other chemicals can help some environmental problems.

Words to know

acid - a compound that increases the number of hydrogen ions (H+) in solution with water. All acids have a pH below 7.

atom - a very, very small particle that makes up all matter.

base - a compound that decreases the number of hydrogen ions (H+) in solution with water. All bases have a pH above 7.

element - a substance made of all the same type of atoms.

indicator - a chemical that changes color with changes in pH.

ion - an atom or molecule with an electrical charge.

matter - anything that has mass and occupies space.

molecule - a group of at least two atoms held together in a definite arrangement.

mixture - two or more materials that are mixed together but not chemically bonded.

pH - a scale that measures relative acidity and basicity.

pollutant - a chemical that is unwanted in a particular environment.

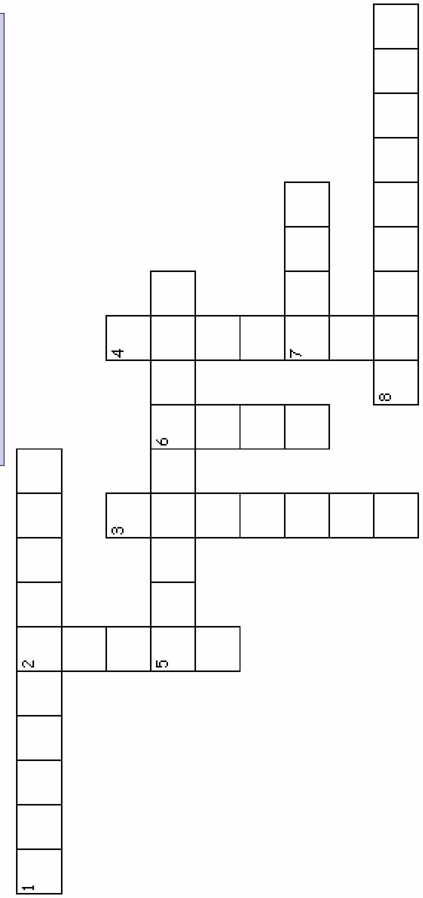
recycling - using a substance or parts of a substance more than once.

solution - a completely uniform mixture of atoms, ions, and/or molecules.

soluble - able to dissolve in another substance.

toxin - a chemical that is harmful to living things.

Use the clues and the Words to Know to complete the crossword puzzle.



Across

1. Activated charcoal is a chemical compound used to filter _____ from water.
5. Bromothymol blue, an _____, turns yellow in acids and blue in bases.
7. Soap is a common _____; its pH is greater than 7.
8. People help the environment by _____.

Down

2. Carbon monoxide gas (CO) is a _____, a chemical harmful to living things.
3. Trash is an example of a _____; it is made of many items mixed together that are not chemically bonded.
4. Many minerals in nature, such as calcium (Ca), are _____ (can be dissolved) in water
6. _____ rain contains sulfuric acid (H_2SO_4) and nitric acid (HNO_3)

OMSI

OREGON MUSEUM OF SCIENCE AND INDUSTRY

CheM LaB

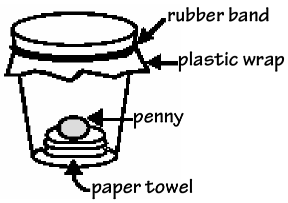
Take-Home Activities

Environmental Chemistry

Iron in the Environment

Why is the Statue of Liberty corroding?

Materials:



1 cup of water
tablespoon measure
salt
vinegar
3 paper towels
2 copper pennies (or pieces of copper wire)
2 iron nails (or paper-covered iron twist ties)
steel wool (or fine sandpaper)
3 small plastic cups
plastic wrap
3 rubber bands

To do and notice:

1. Add one tablespoon of vinegar and a tablespoon of salt to one cup of water. Mix the contents. Fold each sheet of paper towel several times and soak it in the water mixture.
2. Clean all the metal pieces with the steel wool.
   - **What do the metals look like?**
3. Put one paper towel in the bottom of each of the paper cups. Into cup 1, put an iron nail. Into cup 2, put a copper penny. Into cup 3, put a penny and piece of iron together, touching each other.
4. Cover each cup with a piece of plastic wrap secured by a rubber band.
5. Let the cups sit for 2-3 days. Observe the cups each day.
   - **What is happening to the metals in each cup?**
   - **Which piece of metal shows the most change?**

A closer look:

The combination of salt and acid (vinegar) in the water helps cause the corrosion (oxidation) of iron. Iron combines with oxygen to form rust (iron oxide). If the iron is in contact with copper, the copper accelerates this reaction.

The Statue of Liberty is corroding quickly because the iron inner structure is in contact with the copper outer structure and is also in contact with moist, salty sea air

Recycling Paper

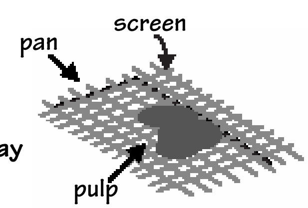
Make your own paper!

Materials:

paper to recycle
water
bowl
flour (or cornstarch)
shallow pan or dish (about 6 inches by 8 inches)
screen (about 8 inches by 10 inches)
blender
tape
rolling pin

To do and notice:

1. Tear half a sheet of paper into small, stamp sized pieces. Put the paper pieces in the bowl and cover them with water. Let the papers soak until they are completely wet.
2. Add ¾ cup of water to the blender. Add the wet papers on top of the water. Blend the paper and water to form a thick pulp.
3. Add two teaspoons of flour to the mixture. Blend again until smooth.
4. Place the screen over the shallow pan. To keep the screen flat, tape the edges of the screen to the pan. **CAUTION: A wire screen may have sharp edges.**



5. Slowly pour the pulp mixture over the screen. Use a rolling pin to smooth the paper over the screen in an even, thin layer.
6. Let the paper sit and drain into the pan for at least one day until it is completely dry.
7. When the paper is dry, carefully peel it from the screen.
   - **What is your paper like?**
   - **Can you write on it?**

A closer look:

Paper is made from very large, long molecules of cellulose. Water dissolves the cellulose and the blender breaks it down. Then the flour binds the cellulose molecules to each other again.

The more you roll the wet fibers, the thinner and flatter your paper will be. You can try adding glitter, seeds, or bits of colored paper to make designs in your paper.

Water Ways

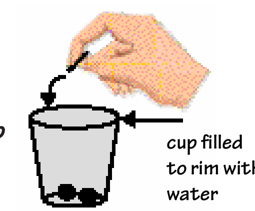
What is surface tension? How can it change?

Materials:

2 small, identical plastic cups or glass jars
1 larger cup
several pennies (or paperclips)
water
liquid soap

To do and notice:

1. Rinse the small cups with water.
2. Fill one small cup to the rim with water.
3. In the larger cup, mix 2 tablespoons of dish soap with tap water. Skim the foam off the top. Slowly pour the water-soap mixture into the second small cup. Fill it to the rim.
4. Carefully drop a penny into the cup with plain water.
   - **What happens?**
   - **How many pennies can you drop in before the water overflows?**



5. Carefully drop a penny into the cup with soapy water.
   - **What happens?**
   - **How many pennies can you drop in before the water overflows?**

A closer look:

You are looking at a property of water called "surface tension." Water molecules attract each other, allowing water to form a dome above the surface of each cup. When you add soap to the water, the soap molecules interfere with the water molecules' ability to bond to each other. This reduces the surface tension of the soapy water, so it cannot support a dome above the rim of the cup.

Surface tension is an important part of the environment. Waterstrider bugs walk on water because the surface tension of the water is strong enough to support their weight. **What would happen if waterstriders tried to walk on soapy water?**

Kool Colors

Learning Objectives: Students learn how different factors affect the rate of chemical reactions.

GRADE LEVEL

2–8

SCIENCE TOPICS

Solutions and Mixtures
Techniques
Chemical Reactions

PROCESS SKILLS

Describing and Defining
Hypothesizing
Controlling Variables
Evaluating

GROUP SIZE

2–4

SNEAK PEAK inside …

ACTIVITY

Students add steel wool to various types of Kool-Aid™ and watch for the color to fade.

STUDENT SUPPLIES

see next page for more supplies

steel wool
Kool-Aid
plastic cups
classroom clock or watch …

ADVANCE PREPARATION

see next page for more details

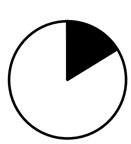
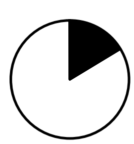
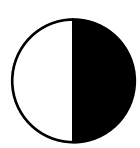
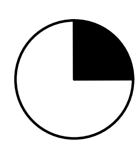
Cut up steel wool
Mix Kool-Aid solutions …

OPTIONAL EXTRAS

DEMONSTRATION
Liquid Bleach and Kool-Aid (p. E - 5)

EXTENSIONS
Inquiry Opportunity—Surface Area and Reaction Rate (p. E - 11)
Inquiry Opportunity—Concentration and Reaction Rate (p. E - 12)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
10 minutes	**10 minutes**	**30 minutes**	**10 minutes**

SUPPLIES

Supplies Note:
The table below lists supplies for testing one color of Kool-Aid at three different temperatures.

For older students, make multiple colors of Kool-Aid for students to repeat the experiment. Multiply the supply needs by the number of colors you are testing.

Item	Amount Needed
fine grade (#000 or #0000) steel wool	3 small clumps, 1 tablespoon each, per group
unsweetened Kool-Aid™ (grape, black cherry, cherry, strawberry, watermelon-cherry, and orange all work)	1 cup per group (1–3 packets total per class)
clear plastic cups, 4 oz. or larger	4 per group
spoons, plastic	1 per group
stopwatch or line of sight to a clock with a second hand	1 per group
masking tape	1 roll for teacher
access to hot water (from the tap, from a microwave, etc.)	
access to fridge	
pop-top squeeze bottles (e.g., water or sports drink)	3 per group
paint color strips from paint store (optional) * See Notes and Hints in Advance Preparation	1 or more per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Kool-Aid:
- ❑ If you are using multiple colors of Kool-Aid, repeat the directions below for each color of Kool-Aid.
- ❑ Don't buy sugarless or "sugar already added" Kool-Aid. Look for the small packets with the concentrated flavor powder alone.
- ❑ Use the package directions to add the appropriate amount of water to the Kool-Aid powder. Do not add sugar.
- ❑ Fill pop-top squeeze bottles with ¼–½ cup of Kool-Aid solution.
- ❑ Label the bottles with the color of Kool-Aid.

- Put one third of the bottles in a refrigerator overnight. Label these "cold."
- Keep one third of the bottles at room temperature. Label these "room."
- The final third of the bottles are for hot Kool-Aid solution. Label these bottles "hot." You can put these in a hot water bath to warm them up just before class starts.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Steel Wool:

- Use scissors to cut the steel wool into portions equal in size to a cotton ball (about 1 tablespoon or 1 gram each).
- Choose the finest possible grade of steel wool (Grade: #000 or #0000); fine steel wool reacts with the colors in Kool-Aid faster than coarse steel wool.
- Use only pure steel wool, not the kind with soap on the surface (e.g., SOS Pads).

Notes and Hints

Paint Color Strips:

This activity requires students to have some way to evaluate color changes. Here are two options:

- The procedure tells students to start with four cups with Kool-Aid, but they only add steel wool to three of them. In the fourth cup, the solution will remain the same color and not fade, so students can compare their reaction cups to it.
- Bring a sample of Kool-Aid solution to a paint store and look for sample color strips that match. With luck, the Kool-Aid will start as one of the darkest colors on the strip. Then it will fade through the lighter versions of the color. This gives the students a way to quantify the color of the solution as it changes.

Kool-Aid:

- Watermelon-cherry, cherry, and orange Kool-Aid fade to colorless. Black cherry and grape change from purple to blue.
- Try to select flavors that include different combinations of dyes (the dyes are listed in the ingredients).

Flavor	Dyes
Black Cherry	Red 40 Blue 1
Cherry	Red 40 Blue 1
Grape	Red 40 Blue 1
Orange	Red 40 Red 40 Lake Yellow 5
Watermelon-Cherry	Red 40

SETUP

For each group

Set out these supplies for each color of Kool-Aid.

- ❑ 4 clear plastic cups
- ❑ 3 clumps of steel wool
- ❑ ¼–½ cup of Kool-Aid solution in a pop-top squeeze bottle at **each** temperature you will measure:
  - ❑ room temperature
  - ❑ refrigerated
  - ❑ hot (as hot as possible from the tap)
- ❑ 1 plastic spoon
- ❑ 1 stopwatch or line of sight to a clock with second hand
- ❑ paint color strips (optional)

At a central location (or with the teacher)

- ❑ towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

This activity has a carefully designed procedure. Take some time to discuss with students why the activity is designed the way it is.

For more information about experimental design, see the **Science Inquiry** section at the beginning of the Guide.

Today we are going to investigate how to make chemical reactions go faster or slower. Can anyone name a very fast chemical reaction? How about a slow one?
Examples of fast reactions are explosions, acid-base reactions like vinegar and baking soda, rocket launches, forest fires, etc. Examples of relatively slower reactions are rusting, photosynthesis, bread rising (yeast reaction), digestion, food going bad, etc.

All of these reactions can be sped up or slowed down by changing the temperature. For instance, food goes bad much more slowly when it is stored in the fridge, and bread rises much faster in a warm location than a cold one.

In order to investigate the effect of temperature more, I've brought in a very interesting problem for us to work on.
Show students the back to one of the Kool-Aid packets and point out that the last line in the directions says "Do not store in a metal container."

Why do you think that direction is there? What do you think will happen if we mix metal and Kool-Aid?
Answers will vary. Encourage the class to form some hypotheses.

Will what we do be affected by temperature? Why or why not?
Yes it will be affected, because temperature affects the rate of all chemical reactions.

TEACHER DEMONSTRATION

Bleach with Kool-Aid
In this demonstration, the instructor adds a tiny amount of bleach to solutions of Kool-Aid to watch the color fade. You can do this demonstration as an introduction before the activity or as a follow up after the activity.

This demonstration is similar in structure to the activity ***Color Me Blue***. For more information on the chemistry of bleach, see that activity.

Supplies
- about 1 cup of any color Kool-Aid solution in a clear plastic cup, include as many other colors of Kool-Aid as desired
- 1 spoonful diluted bleach solution for each cup of Kool-Aid to be tested
  - prepare diluted bleach solution by adding 5 drops of bleach to 2 cups water

CAUTION: Full strength bleach is a corrosive and hazardous substance. Wear gloves and use care when handling.

Demonstration

- Point out the colored Kool-Aid cups and ask students to guess which colors are present in each (e.g., students might guess that red and blue colors are in purple Kool-Aid).
- Point out the bleach and discuss how it works. Ask students whether it bleaches all colors equally. Solicit stories of hair coloring or artificial tanning solution to establish the potentially mysterious results of adding color-changing chemicals together.
- If time permits, collect student hypotheses on what the bleach will do to each Kool-Aid solution. Ask students to provide reasons behind their hypotheses, if they have them.
- Add 1 spoonful of dilute bleach solution to each Kool-Aid solution. Observe for any changes.

Explanation

Full strength bleach reacts with many dyes in clothes and food. The reaction can destroy the dye. Dilute bleach reacts with only certain types of dyes. In this demonstration, you may see that some of the Kool-Aid colors fade and others do not.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page E - 15, working in groups of 2–4. The following are suggestions to help the teacher facilitate the activity.

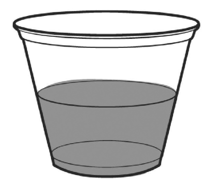
NOTES

This handout is on p. E - 15.

Kool Colors

SCIENTIFIC PROCEDURE

1. Label four cups "Cold," "Room Temp," "Hot," and "No Steel Wool."
2. Add 4 spoonfuls of cold Kool-Aid into the cup labeled "No Steel Wool."
   - **Record:** Write the flavor of Kool-Aid at the top of the Data Table.
   - **Record:** Write the initial color of the Kool-Aid on the Data Table.



3. Look at the pieces of steel wool.

Running Suggestions

- Groups of three students work well, then each student can test the reaction at a different temperature.
- Discuss with students how they will decide when the Kool-Aid has finished changing color. Brainstorm and have the class arrive at a method that they will consistently use.
- Have students place their clear plastic cups over a white piece of paper so they can see the color changes better.
- Have groups of students analyze all three temperatures or give different temperatures to different groups and collect all class data to discuss at the end.
- If you are testing different colors of Kool-Aid, students should complete all the tests with one color first. Then they can repeat the experiment with another color.
- Show students the ingredients lists on the back of the original drink packets. Students can see and record the particular dyes they are investigating.
- Use paint color test strips so students can compare the color of the Kool-Aid solutions during the reaction.

Ongoing Assessment

- What colors are you seeing? Has the Kool-Aid changed at all? *(Answers will vary.)*
- How can you tell when the reaction is finished? *(This is important for students to answer, have them compare their solutions with each other or with the original Kool-Aid.)*
- What is happening to the steel wool? How is it changing, if at all? *(Students might see it turning dark in color; small clumps may be visible on its surface.)*

Safety and Disposal

- Kool-Aid solutions may be poured down the sink.
- Steel wool should be thrown away in the trash.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated from other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Upon carefully observing the color changes in each batch of Kool-Aid, students should be able to notice patterns in how the colors changed. For instance, if steel wool turned a cup of Kool-Aid with Red 40 clear, students might notice that other Kool-Aid solutions with Red 40 also changed color.

Create a chart with the data from each group.

What happened to the Kool-Aid solutions? What happened to the steel wool?
The color changed/dissappeared. When the steel wool was removed from the Kool-Aid solutions, it was black rusty.

What does your data show? Which colors of Kool-Aid reacted with the steel wool?
Answers will vary based on the Kool-Aid chosen.

Did the color change happen faster in warm water, room temperature water, or cold water?
Hot water changed the color the fastest, room temperature the next fastest, and cold water changed the slowest.

Why do you think hot water changed the color faster?
The mixture with hot water had more energy (heat) in the system, so the reactions were able to happen faster, causing the color change to occur earlier.

Which chemical was left over after the reaction: the Kool-Aid color or the steel wool? How do you know?
The steel wool is left over. We know because we can see it!

Discuss with students the design of the experiment they conducted.

For detailed information about experimental design, see **Science Inquiry** in the beginning of the guide.

EXPLANATION

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

Students learn how they can change the speed of a chemical reaction by changing the temperature of the ingredients.

BACKGROUND FOR ALL GRADES

Chemical Reactions

In **chemical reactions**, substances interact and transform each other. In this experiment, the steel wool (which is mostly iron but with small amounts of other metals) reacts with the dyes in the Kool-Aid to remove the color of the solution. This color change is evidence of some kind of chemical reaction. This chemical reaction can be sped up or slowed down by changing the temperature of the Kool-Aid.

Color Change

As shown by the ingredient lists on the back of the package, each flavor of Kool-Aid contains different combinations of food dyes, including FD&C Red 40, FD&C Blue 1, or FD&C Yellow 5. The red and yellow dyes will react with steel wool and lose color, while the blue dye will not. This means that flavors that use only red and yellow dyes will fade completely. A flavor of Kool-Aid that uses a combination of blue with red or yellow dyes will fade so that only the blue color is left behind.

Effect of Temperature on Reaction Rate

The speed of a chemical reaction is called the **reaction rate**. By altering the conditions in a chemical reaction, scientists can speed up or slow down the reaction rate. In this experiment, hot Kool-Aid solutions reacted faster than cold ones because the increased energy in hot solutions causes the steel wool and

Kool-Aid colors to collide together more quickly and effectively (see below for more info on this).

Experimental Design
Scientists often want to know what will happen if they change something about an experiment. To investigate this, they carry out their tests while changing only one factor at a time. Each factor that can change in an experiment is called a **variable**.

For more information about experimental design, see the section *Science Inquiry* in the beginning of the Guide.

In this experiment, students conduct the same experiment three times but at different **temperatures**. All the reactions use the same amount of steel wool and the same amount of Kool-Aid solution at the same concentration. The only difference between the reactions is the temperature of the Kool-Aid solution. Since everything else is the same, students can be sure that any change to reaction rate is due to the difference in temperature.

If students repeat the test with different colors of Kool-Aid, they again need to keep everything the same and only change the color of the Kool-Aid. This way they can compare the reaction rate between two different colors of Kool-Aid at the same temperature. The extensions provided at the end of this experiment also suggest other variables that can be tested: **surface area** of steel wool (Extension A) and **concentration** of Kool-Aid dye (Extension B).

EXTRA BACKGROUND FOR GRADES 5–8

Dye Composition
The Red 40, Red 40 Lake, and Yellow 5 dyes in Kool-Aid react with steel wool because their **molecules** are similar. These dyes are called **azo dyes**. This means that somewhere in the dye molecule there are two nitrogen atoms with a "double bond" between them. The iron in steel wool reacts with and changes this bond. This changes the shape of the dye molecule and removes its color.

Other dyes, such as Blue 1, do not have this structural feature, and they keep their color in the presence of steel wool.

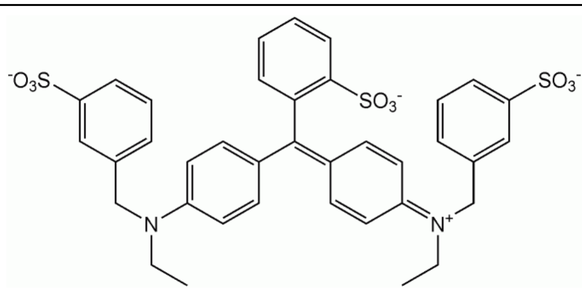


Figure 1. Dye structure for Blue 1 food coloring. Notice the lack of a nitrogen-nitrogen bond.

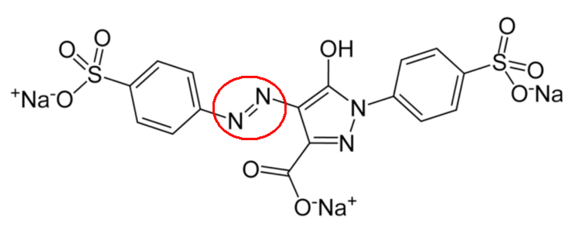


Figure 2. Dye structure for Yellow 5 food coloring with the nitrogen-nitrogen bond highlighted.

Oxidation and Reduction
The type of reaction seen in this activity is known as an oxidation-reduction reaction. The steel wool in this activity loses electrons and is said to be **oxidized**. Students can observe this by looking at the steel wool afterward. The steel wool may turn black or may show signs of rust. Steel is primarily made from iron, and, when iron oxidizes, we call it rust.

If something loses electrons, something else must gain those electrons. In this case, the dye in the Kool-Aid solution is gaining electrons and is said to be **reduced**. When the dye reacts and becomes reduced, its color fades.

Temperature and Reaction Rate
Chemical reactions happen when **molecules** bump into each other with enough **energy** or force. In this experiment, for instance, dye molecules from the Kool-Aid must physically collide with an iron atom in the steel wool before it will react. The rate of this reaction depends on how often the molecules bump into each other and on how much energy they have when they do so.

Increasing the **temperature** increases the reaction rate because it increases both the number of collisions between molecules and the energy of those collisions. At high temperatures, molecules are shaking, twisting, and zooming around much faster than at lower temperatures. Molecules that move faster will tend to collide more forcefully, increasing the likelihood that collisions between molecules will result in a chemical reaction. In addition, molecules moving faster collide more often, and more collisions means more reactions.

Surface Area and Reaction Rate
As shown in Extension A below, the **surface area** of the steel wool is another factor in the rate of the reaction. Steel wool has a relatively large surface area compared to, say, a chunk of steel of the same weight. Along the same lines, fine grades of steel wool have more surface area exposed than coarser grades. When more steel is exposed, more collisions are possible, and the reaction rate goes up.

EXTENSIONS

Extension A: Inquiry Opportunity—Surface Area and Reaction Rate
Test different grades of steel wool to see how surface area affects the rate of reaction.

Extra Supplies
- other grades of steel wool (#3, vs. #1, vs. #00 vs. #0000, for example)

Extra Instructions
- Repeat experiment but use only one flavor of Kool-Aid and change the grade of steel wool used.
- **Note:** very coarse steel wool (e.g. #3) can take up to an hour to react.

Explanation

Finer steel wool means there is more surface area of steel wool to react with the dyes. When there is more opportunity for molecules to interact, the reaction goes faster.

Extension B: Inquiry Opportunity—Concentration and Reaction Rate

Students investigate how the rate of reaction changes when the concentration of the Kool-Aid changes.

Extra Supplies

- extra Kool-Aid to make double or triple strength solutions

Extra Instructions

- Create solutions of higher or lower concentrations of Kool-Aid for students to try out.
- If students investigate the effect of concentration on rate, they should conduct their experiments on solutions of the same temperature.

Explanation

If students use double the concentration of Kool-Aid, and the reaction goes at the same rate, they should expect the color to take twice as long to fade. If it takes less than twice as long, then the reaction is happening faster at the higher concentration. If it takes more than twice as long, then the reaction is happening slower at the higher concentration.

It is more likely that the reaction rate will increase at higher concentrations of Kool-Aid solution. This is because with more dye molecules, there are more opportunities for collisions and reactions to occur between the dye and the steel wool.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS

Graphing Reaction Rate

The relative rates of reaction at different temperatures can be measured and graphed. Use thermometers to measure the temperature of different Kool-Aid solutions and then measure how long it takes for the color to fade.

Ratios

Like other rates, the rate of reaction is a ratio. After completing Extension B, students can calculate the rate by dividing the amount of Kool-Aid divided by the time of reaction. They can compare the numbers to see which reaction has the fastest rate (the highest value).

SOCIAL STUDIES

The History of Color

Dyes and pigments were precious commodities in ancient times and their presence often indicated nobility or extreme wealth. Medieval alchemists struggled to create them and the nobility directed the efforts of nations toward acquiring them. Research into creating synthetic dyes in Germany in the 19^{th} century gave rise to the modern chemical industry. Many books detail this fascinating history (see below).

ART

Tie Dye

Use concentrated Kool-Aid to tie dye different fabrics. This dye is not permanent.

RESOURCES

Web – http://www.chemguide.co.uk/physical/basicratesmenu.html#top
A great Web site with sections on all areas of reaction rates: theories, causes, factors, etc.

Web – http://jchemed.chem.wisc.edu/HS/classact/ClassActsList.html
The activity "A Kool Reaction from the Fine Print" on this page provides an alternative version of this activity, along with student questions and further information on the chemistry behind the reaction. Scroll down to the link and click through to the PDF file.

Delamare, Guineau and Francois, Ber, *Colors: The Story of Dyes and Pigments*
Reading level: 6^{th}–8^{th} grade
This small book details the history and uses of colors over the ages, from cave paintings to medieval alchemy to modern textiles. It is packed with colorful pictures and small anecdotes about color, dye-making, and the use of pigments.

VOCABULARY

azo dyes: a class of clothing and food dyes which contain a nitrogen-nitrogen double bond

chemical reaction: the foaming, heating, cooling, glowing, color change, or appearance of something new when two or more chemicals are mixed together

concentration: the ratio of the amount of a chemical in a solution to the volume of the solution

energy: the ability to do work; anything that is not matter

molecule: a group of at least two atoms held together in a definite arrangement

oxidize: in a chemical reaction, to lose electrons; always paired with a reduction process

reaction rate: the speed at which two chemicals react with each other

reduce: in a chemical reaction, to gain electrons; always paired with an oxidation process

surface area: the amount of accessible space for a reaction to happen

temperature: a measure of the warmth of a substance, based on how fast its molecules are moving

variable: a changeable factor in a scientific experiment

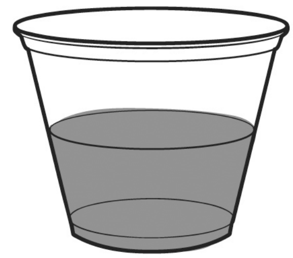
Kool Colors

SCIENTIFIC PROCEDURE

1. Label four cups “Cold,” “Room Temp,” “Hot,” and “No Steel Wool.”

2. Add 4 spoonfuls of **cold** Kool-Aid into the cup labeled “No Steel Wool.”

- **Record:** Write the flavor of Kool-Aid at the top of the Data Table.
- **Record:** Write the initial color of the Kool-Aid on the Data Table.



3. Look at the pieces of steel wool.

- **Record:** Describe what the steel wool looks like at the beginning of the experiment. Write this on the Data Table.

4. Add 4 spoonfuls of **cold** Kool-Aid into the cup labeled “Cold.”

5. Add a clump of steel wool to the **cold** Kool-Aid in the cup.

- **Record:** Write the beginning color of the cold Kool-Aid.
- **Record**: Every 30 seconds, write the color of the Kool-Aid on the Data Table.
- Continue for 5 minutes.

6. Add 4 spoonfuls of **room temperature** Kool-Aid into the cup labeled “Room Temp.”

7. Add a clump of steel wool to the **room temperature** Kool-Aid in the cup.

- **Record:** Write the beginning color of the room temperature Kool-Aid.
- **Record:** Every 30 seconds, write the color of the Kool-Aid on the Data Table.
- Continue for 5 minutes.

8. Add 4 spoonfuls of **hot** Kool-Aid into the cup labeled "Hot."

9. Add a clump of steel wool to the hot Kool-Aid in the cup.

- **Record:** Write the beginning color of the hot Kool-Aid.
- **Record:** Every 30 seconds, write the color of the Kool-Aid on the Data Table.
- Continue for 5 minutes.

10. Take the steel wool out of all the cups.

- What does the steel wool look like now?
- **Record:** Describe what the steel wool looks like at the end of the experiment. Write this on the Data Table.

11. Clean up your area.

- Follow your teacher's directions.

Kool Colors

DATA SHEET

Flavor of Kool-Aid Tested: ____________________

	Types of Kool-Aid (Record color of Kool-Aid below)		
Time (minutes)	Cold Kool-Aid	Room Temp Kool-Aid	Hot Kool-Aid
Begin (0:00)			
0:30			
1:00			
1:30			
2:00			
2:30			
3:00			
3:30			
4:00			
4:30			
5:00			

Steel Wool	Beginning Appearance	Ending Appearance
Record observations here →		

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Kool Colors

Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
fine grade (#000 or #0000) steel wool	3 small clumps, 1 tablespoon each, per group		
unsweetened Kool-Aid (grape, black cherry, cherry, strawberry, watermelon-cherry, and orange all work)	1 cup per group (1–3 packets total per class)		
clear plastic cups, 4 oz. or larger	4 per group		
spoons, plastic	1 per group		
stopwatch or line of sight to a clock with a second hand	1 per group		
masking tape	1 roll for teacher		
access to hot water (from the tap, from a microwave, etc.)			
access to fridge			
pop-top squeeze bottles (e.g., water or sports drink)	3 per group		
paint color strips from paint store (optional) * See Notes and Hints in Advance Preparation	1 or more per group		
Extension A			
other grades of steel wool, e.g., #00, #0, #1, etc.	3 small clumps per group		
Extension B			
additional packets of Kool-Aid	1–3 per class, depending on the concentration desired		
Teacher Demonstration			
Kool-Aid solution	1 cup each color		
clear plastic cup	1 per Kool-Aid flavor		
diluted bleach solution (5 drops of bleach to 2 cups of water)	1 spoonful per Kool-Aid flavor		

Odors Aloft

Learning Objectives: *Students infer the presence and motion of scented molecules.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Atoms and Molecules
Techniques

PROCESS SKILLS

Describing/Defining
Inferring
Evaluating

GROUP SIZE

1–2

SNEAK PEAK inside …

ACTIVITY

Students smell balloons filled with different scents to guess what's inside.

STUDENT SUPPLIES

see next page for more supplies

balloons
scent substances (extracts, etc.)
string, etc.…

ADVANCE PREPARATION

see next page for more details

Fill balloons with scents
Label balloons
Blow up and tie balloons, etc.…

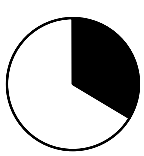
OPTIONAL EXTRAS

DEMONSTRATIONS
How Chemists Smell (p. E - 23)
Modeling States of Matter (p. E - 23)
Molecule Size and Diffusion (p. E - 24)

EXTENSIONS
Odor Diffusion (p. E - 29)
Extract Essential Oils (p. E - 30)

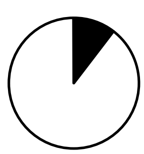
TIME REQUIRED

Advance Preparation



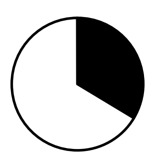
20 minutes

Set Up



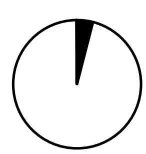
5 minutes

Activity



20 minutes

Clean Up



2 minutes

SUPPLIES

Item	Amount Needed
balloons	1 per scent used
permanent marker	1 per class
straw, pipette, or eyedropper	1 per class (washing out between uses) or 5–10 disposable
A selection of odor substances, for example: anise extract, vanilla extract, coffee extract (or very strong coffee), almond extract, peppermint extract, lemon extract, root beer concentrate, imitation chocolate flavor, imitation orange flavor, cinnamon, curry powder, ground cloves or clove oil, aftershave or perfume, baby lotion or baby powder, camphor- or eucalyptus-containing compound, e.g., Mentholatum or Vicks VapoRub Other nontoxic spices, extracts, or strong smelling substances with which the students may be familiar	1–2 teaspoons of spice powder or ½ teaspoon of liquid extract (depending on the strength of the extract) per class

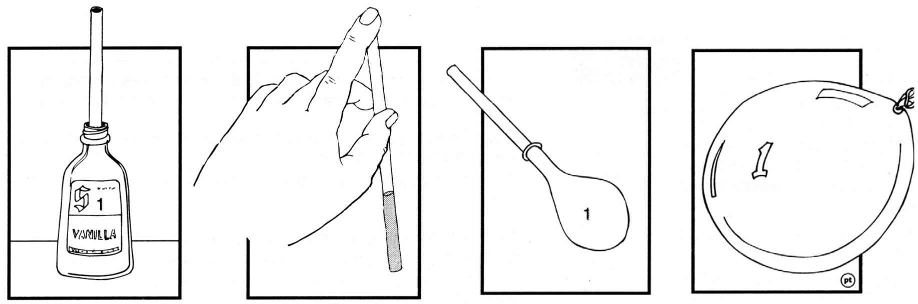
For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Odor Balloons

- Assign a number to each odor you will use.
- Use the same number for all balloons with the same odor.
- Fill the uninflated balloons with an odor substance. Be careful not to spill the odor substance on the mouth of the balloon. (See illustrations on the following page.)
  1. Collect some of the odor substance (less than 1 tsp for liquid extracts, 1–2 tsp for spice powders) using a straw, a pipette, or an eyedropper. Use your finger on the top of the straw to trap both liquids and solid powders in the bottom.
  2. Insert the straw, pipette, or eyedropper into the mouth of balloon #1.



3. Release the contents into the balloon. (NOTE: this technique even works to transfer powders, if you are careful. Alternatively, use the end of the straw to scoop the powders and transfer.)
4. Remove the straw, pipette, or eyedropper.
5. Smell the balloon—can you smell some of the odor leaking out? If not, add slightly more spice or extract.
6. Blow up the balloon and tie it closed. Be careful not to let the balloon deflate until it is tied closed.
7. Using a permanent marker, number the balloon to match the odor numbers you choose. (You may choose to use the same odor more than once.)
8. If you are using a reusable eyedropper, clean the eyedropper to completely remove the odor by rinsing the dropper well with hot, soapy water, then with plain hot water several times.
9. Clean the mouth of the balloon if any odor substance was spilled onto the outside of the balloon.

- Repeat steps 1–9 for each odor.

Notes and Hints

- For most substances (except weak smelling extracts, such as almond, and older extracts), the balloons can be prepared the morning before the activity. However, the activity works best when the balloons have been freshly prepared.
- If you prepare the balloons ahead of time, do not store them next to each other (for instance, in a large box or bag)—the odors will escape from each balloon and pass into other balloons (especially peppermint extract).
- If you use a straw, dip the bottom end of your straw about 1 inch into the odor substance, then hold your finger over the top of the straw until the straw with the odor substance is inserted into the balloon. When you release your finger from the straw, the odor substance will drop into the balloon.

SETUP

For each station

- 1–2 numbered scent balloons

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

What are molecules? What are atoms?
Atoms are the tiniest bits of matter, i.e., what you get upon chopping matter as small as possible. The Greek word "atomos" means indivisible. Molecules are atoms connected together into larger arrangements. Both atoms and molecules are much too small to see, even with a microscope.

If individual atoms are tiny and invisible, why do people think they exist? What evidence do we have that tiny, invisible things like atoms exist?
Atoms aren't visible through regular microscopes, although scientists have seen atoms with powerful electron microscopes in recent years. Microscopes do show that there are many things in the world too small for people to see with their eyes (dust mites, bacteria, etc.). Some students might point out that we can feel invisible air moving (it pushes us fairly hard in a windstorm). This air must have weight (mass), even though we can't see it.
Collect student answers, discriminating between inferences (conclusions based on evidence) and the actual evidence.

Today we are going to use our bodies to collect information about how small molecules are, as well as about how they move around.

FOR GRADES 3–8
Who can tell me the differences between solids, liquids, and gases?
A solid is hard, it keeps its shape. A liquid is fluid and takes the shape of its container. A gas has no fixed shape and expands constantly.

Are solids, liquids, and gases all made of atoms or molecules? If you think so, why? If not, why not?
Students might point out that each substance can be divided into smaller and smaller parts, so that, logically speaking, such a cutting process would eventually produce atoms or molecules. Students might know that atoms and molecules have mass, and that solids liquids and gases have mass.

Although solids, liquids, and gases are all made of atoms or molecules, this can be hard to prove. Indeed, it was only in modern times that visual evidence (e.g., pictures) of atoms and molecules was first produced.

Let's talk about air, a mixture of gases. If you blow up a balloon and then leave it for a couple days, what happens? Why do you think this happens?
The balloon shrinks because the air gets out. If air can get out, it must be made of pretty small particles. In fact, the air molecules are small enough to fit between tiny, invisible holes in the walls of the balloon and escape.
In the activity, students will observe balloons that are filled with smelly solids and smelly liquids. Somehow the smell gets outside of the balloon (the molecules of the solids and liquids evaporate and become gas molecules, which then escape through tiny pores in the balloon).

TEACHER DEMONSTRATION

How Chemists Smell
Since this activity uses the sense of smell, you may wish to demonstrate how chemists smell things in a lab. They never stick their noses next to an unknown chemical and inhale, because sometimes chemicals have harmful or toxic fumes—or they just stink.

To smell unknown substances in the lab, chemists hold open containers away from their noses and use their hands to gently wave a small amount of the substance toward their noses. (Demonstrate this action.)

Modeling States of Matter
Students play a game to illustrate how molecules behave in the three states of matter.

Demonstration

- Put students in one large group and have them link arms. Each student is a molecule. Their linked arms represent the attractive forces between molecules.
- First students will imitate a **solid**. Have them link arms very tightly and squeeze in close together. They are able to move a little but not much because the molecules are so close together. Jumping up and down, bending side to side, and twisting back and forth are all allowed, but not unlinking arms.
- Next, students become a **liquid**. Changing from a solid to a liquid is called **melting**. Students hold hands and move farther apart from each other. Occasionally they can switch and hold hands with someone new. They can move more easily but are still bound together. Notice how the molecules have expanded to fill more of the room.

- Next, students imitate a **gas**. Changing from a liquid to a gas is called **boiling**. Gas molecules move much more quickly and each molecule acts on its own. The students let go of their classmates and move in straight lines across the room, until they run into something and bounce off of it. They then change directions. Notice how students quickly expand to fill the entire room. (If you are brave, remind students that they can still jump, bend, and twist while they are gases!)
- Have students go back to being a liquid. Changing from a gas to a liquid is called **condensing**. Students should move more slowly and hold hands with neighbors.
- Finally students become a solid. Changing from a liquid to a solid is called **freezing**. Students should link arms again, move much more slowly, and move closer together. If you want to remind students that at lower temperatures, molecules tend to form solids, you can have them shiver at this point.

Molecule Size and Diffusion

This demonstration is best to do after the activity and is recommended for grades 4–8.

Students see how the size of the scent molecules in the balloon affects how fast they escape through the balloon membrane.

Demonstration

- Create a large central space in the classroom with a perimeter of desks, if possible. Tell the class that the perimeter represents the walls of a balloon. Create a "pore" in the wall of the balloon by moving two desks or tables a couple of feet from each other. (Alternatively, treat the entire classroom as a balloon, and leave the door open to represent a pore.) The students will try to travel through this space while acting like gas molecules.
- Put students in groups of 2–5. They are now molecules of different sizes. Remind students that they are gas molecules, which means they can only travel in straight lines and in random directions. When they hit an edge, they bounce off the sides of the balloon until they make it through the "pore" in the membrane.
- Which molecules made it through the pore more quickly than others?

Explanation

Smaller molecules fit through the membrane of the balloon more easily, and their scent fades from the balloon most quickly. Larger molecules need to hit the "pore" in the wall of desks (or the classroom) with a particular orientation in order to fit through it.

Older students can be reminded that larger molecules have more mass and will tend to move more slowly than smaller molecules. This also limits how quickly large molecules can escape through the walls of the balloon.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page E - 33, working in groups of 1–2. Below are suggestions to help the teacher facilitate the activity.

NOTES

This handout is on p. E - 33.

Odors Aloft

SCIENTIFIC PROCEDURE

1. Take turns smelling each balloon. What do you think the balloons smell like? Write your ideas in the "Hypotheses" column.
2. Discuss your hypotheses with your group.
3. When you find out what is making the smell, write this information in the "Actual Smell" column.

Balloon Number	Hypotheses	Actual Smell

Running Suggestions

- Create stations with one or two balloons at each station and have student groups rotate through the stations, or have students stay with two or three balloons at their station and focus on them alone.
- If you choose to set up stations, you may wish to tie balloons to chairs with a bit of string to keep them nearby.
- If you like, set out coffee beans in small cups so that students can "cleanse" their nose after smelling each balloon.
- Create a class chart at the front of the room to record students' final guesses.

Ongoing Assessment

- If students are having trouble naming a certain smell, have them think about what that smell reminds them of (for instance, pumpkin pie, or breakfast, or the beach).

Safety and Disposal

- Take extra care when popping and discarding balloons to the trash as they may stain. To avoid splashing smelly extracts, place a paper towel or two around the balloon and push a pin through the towel, into the balloon.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Create a class chart at the front of the room to record the various student guesses for each odor. Take turns asking students for their guesses. After students have offered guesses for all the odors, reveal the true odors and write the answers.

Did some of the balloons smell more strongly than others? How far away did you need to hold the balloon in order to smell it?
Answers will vary.

How did the smells get into those balloons?
Reveal the liquid extracts and solid spice powders that produced the smells. You can explain how you put the odors into the balloons.

How did the smell get from inside the balloon to outside the balloon?
Tiny, invisible bits of the smell must have passed through holes in the balloon that we can't see.

If the scent substance inside the balloon is a solid (for example, curry powder), how did those molecules get through the balloon and to our nose?
Collect student answers and hypotheses. We smell odors when the molecules of a substance reach our nose. Some of the solid must have turned into a gas and then traveled through the balloon to our nose. (Remind students that in solids and in liquids, molecules are partially or entirely connected to each other, meaning they are in bigger chunks that won't fit through the tiny holes in the walls of the balloon.)

If you feel adventurous, you can make this point particularly well by discussing the smelling of farts.

How much of a substance is necessary for us to smell it?
We can smell very small amounts of some odors. Our sense of smell is our most delicate sense. We can smell as little as one molecule of some substances. We certainly cannot see a single molecule with our naked eye. In fact, we cannot see most molecules, even with 1,000 X magnification.

Were some odors easier to guess than others? Why?
Some odors are more familiar to the students. Some of the substances release more odor molecules. Some of the odor molecules are better able to escape from the balloon. Also, some individuals have a better sense of smell. Most animals have a much better sense of smell than humans. Many animals can find food, detect enemies, and follow a detailed route using the sense of smell rather than sight.

EXPLANATION

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

In this activity, scent molecules pass through the walls of balloons and travel all the way to each student's nose, allowing him or her to smell the substances from outside the balloon.

BACKGROUND FOR ALL GRADES

Matter

All **matter** is made up of **atoms**. Atoms can be visualized in the following way: take a bar of gold and chop it into tiny pieces, and then chop those pieces into tinier pieces until they cannot be chopped any further. Those pieces, which are each still "gold," are called atoms, from the Greek *atomos* for "indivisible." Atoms are the smallest bit of an element that is still identifiable as that element. They are so small they can't even be seen with a microscope. (Recently some electron microscopes have produced definitive evidence of atoms in the form of pictures.)

When atoms combine they make **molecules**. For example, one molecule of water is made up of one oxygen atom and two hydrogen atoms (Figure 1).

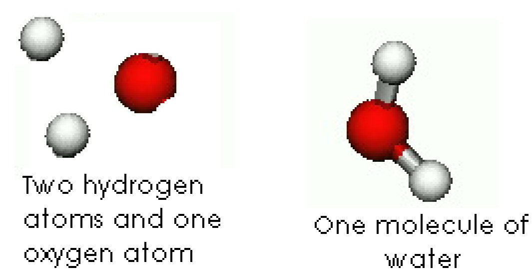


Figure 1. The atoms of water and a molecule of water.

Gases inside Balloons—and outside Balloons

People usually fill balloons with mixtures of gas molecules (in other words: air!). These energetic molecules bounce around inside the balloons and exert a **pressure** that keeps balloons inflated. The walls of a balloon are not perfectly impenetrable to the tiny gas molecules used to inflate them, however. Eventually, the gas molecules escape through tiny pores, or holes, in the walls of the balloon. That is why a balloon deflates.

Floating helium balloons deflate faster than air-filled balloons because helium molecules are much smaller than the nitrogen and oxygen molecules in air and are able to escape through the balloon walls more easily.

Smell

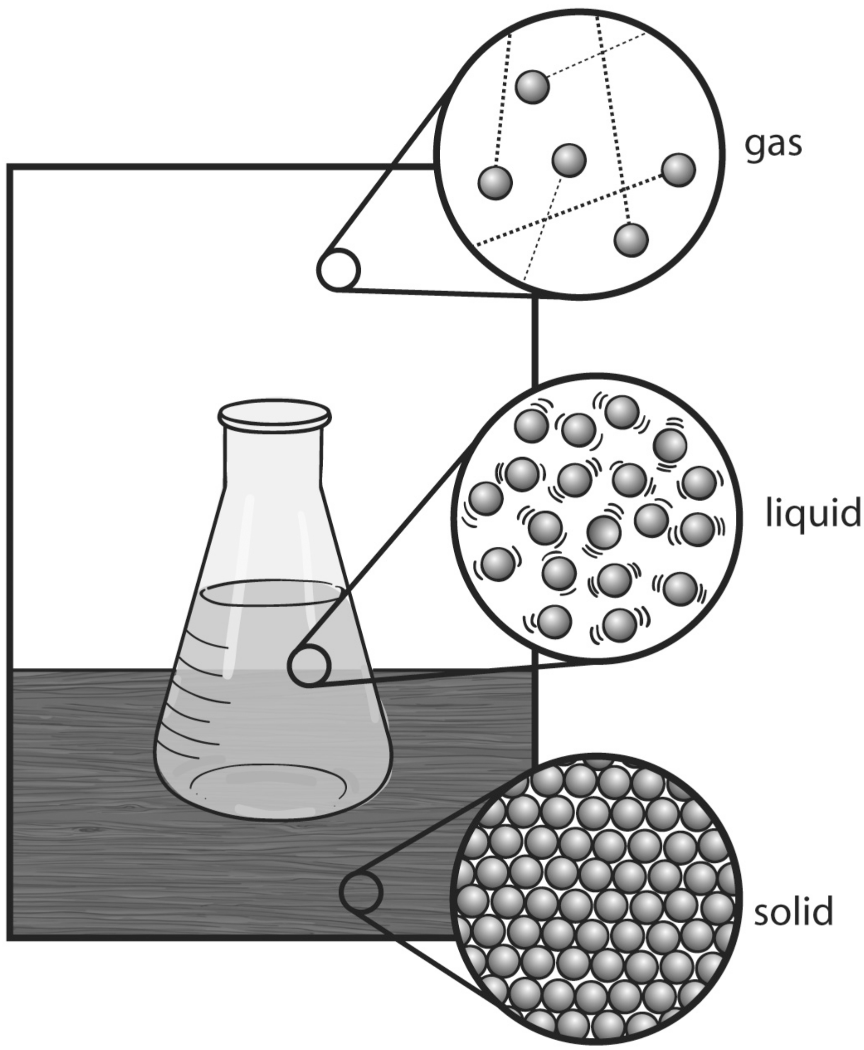
People smell substances when atoms or molecules of that substance collide with special chemical receptors in the nose. The nose can recognize the unique shape and chemical properties of each gaseous molecule or atom. This allows people to tell different atoms and molecules apart, just by smelling them.

States of Matter

Molecules and atoms can exist in three common forms: **solid**, **liquid**, and **gas**. (Other forms exist, but they are unusual and hard to find.) Figure 2 shows these three forms of matter.

- In a solid, the molecules or atoms vibrate, twist, and rotate and are closely packed in a rigid structure.
- In a liquid, the molecules and atoms are able to move around, bouncing off of each other, but also forming small temporary bonds with other molecules. This extra freedom of motion, combined with the force of gravity, allows them to take the shape of their container.
- In a gas, the molecules move in random directions at high speed and quickly fill any space they are in. They move completely independently of each other. Because gas molecules have such tiny masses, and travel at such high speeds, they are mostly unaffected by the force of gravity. (Although it should be noted that the force of gravity does in fact keep the Earth's atmosphere in place.)

Figure 2. Three states of matter.



Gas molecules are spread far apart, zooming around at high speed and often colliding.

Liquid molecules are much, much closer together, colliding and jostling each other constantly.

Solid molecules are packed together in a regular way. They can't move and bounce off of each other, but they do constantly vibrate in place.

Astute students will point out that many solids and liquids have a smell, not just gases. In each of these cases, a small part of the solid or liquid has turned into a gas and traveled through the air to reach the nose.

Evaporation is the process by which liquids gradually turn into gases over time. Evaporation happens at the surface of the liquid. There, thousands of collisions between liquid molecules can randomly give certain molecules enough energy to fly out of the liquid into the air. As this process continues, more and more of the liquid is converted to a gas.

Something very similar to evaporation happens at the surface of solids, although much more slowly. It is called **sublimation—**the transition of a solid directly to a gas without first melting into a liquid.

How does it work at the surface of a solid? In a solid, the atoms aren't free to move around and collide with each other, as in liquids, because they are attracted tightly together. However, each molecule is still vibrating, sometimes quite intensely. Sometimes atoms along the outside of the solid will vibrate enough to detach from the solid and become a gas. Heating causes the atoms to vibrate faster and fly loose, which is why hot foods have more of an aroma.

Chemoreception

A chemical reaction between scent molecules and receptors in the nose produces the sense of smell. Different molecules produce different chemical reactions in the nose and therefore different smells. The sense of smell is an example of **chemoreception**. In chemoreception, living things detect substances in their environment by interacting with them chemically.

Note that some molecules have no smell because the human nose has evolved to react with (smell) only certain scents. Other animals, most notably dogs, have evolved a much finer sense of smell and can recognize many more molecules.

Although scientists have long been puzzled at the exact way smell works, they now feel confident that the shape of the odor molecule is probably the major factor in how it smells.

EXTENSIONS

Extension A: Odor Diffusion

Stand students at regular intervals (at desks in a grid if applicable), open a jar of strong smelling solution, such as a perfume bottle. Alternatively, spray an air freshener in the room. Use a timer and ask students to raise their hands when they smell the solution. Repeat experiment, but use a fan to blow the scent molecules across the room.

Extension B. Extract Essential Oils

Students learn how to extract essential oils from plants using alcohol to make their own extracts.

Extra Supplies

- flowers, fruits, or leaves with appealing aromas (citrus fruit peels, herbs, vanilla pods, cinnamon sticks, and flower petals all work well)
- denatured alcohol (found in hardware stores; isopropyl alcohol also works but is more smelly)
- sealable glass jars
- paper, cut into 1 inch by 1 inch squares

Extra Instructions

- Put the plant material in the sealable jar. Although it will speed up the process, it is not usually necessary to break apart or grind the flower, herb, etc.
- Pour in enough alcohol to cover the material.
- Cover jar tightly and let sit for 4–7 days.
- Remove all solid material from jar. The liquid left over is a solution of alcohol and the essential oil that produces the aroma.
- To best smell the oil, put one or two drops of the alcohol mixture onto a piece of paper and let the alcohol evaporate away. The essential oil remains.

Explanation

Plants often produce what are called essential oils. These oily substances have intense smells and have been prized (or cursed) for their aromas throughout history. Like other oils, these scent molecules in plants are more soluble in alcohol than water. Because the rest of the plant is not soluble in alcohol, soaking the plant in alcohol extracts the scent and other trace oils (such as the pigment of the plant or flower). When the essential oil is applied to a piece of paper, the alcohol quickly evaporates, leaving behind the scent.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS/ PHYSICS

Air Currents

Plot the distance from a substance for an average blindfolded student to smell a particular substance, such as an open bottle of perfume. Change locations to see whether it makes a difference (inside, outside, in a cool place, near the door, near a heater, etc.). Try flying paper airplanes in the same locations. Plot the average distance flown in various locations. Does their average travel distance vary with the air currents?

Alternatively, plot the time it takes for a substance's smell to travel to different parts of the room as in Extension A.

LANGUAGE ARTS

Write a Smell Story

Have students write a descriptive piece, paying special attention to the sense of smell, or have students write a story about a memory that a certain smell provokes.

BIOLOGY

Flower Scents

Have students research why flowers smell differently, and which sorts of smells attract different pollinators.

RESOURCES

Cole, Joanna, *You Can't Smell a Flower With Your Ear!*, Grosset & Dunlap
Reading level: 1st to 4th grade
How do your ears hear? Will food taste the same if you hold your nose? A fun and simple science book—with games and experiments kids can do to test and trick their five senses—by the bestselling author of the Magic School Bus series.

Meisel,Paul, Weidner Zoehfeld, Kathleen, *What Is the World Made Of? All About Solids, Liquids, and Gases*, Harper Trophy
Reading level: 1st to 4th grade
A fact-filled, accessible study of solids, liquids, and gases. The book gives examples of each state of matter and some simple activities that demonstrate the attributes of each.

Cho, Shinta, *The Gas We Pass: The Story of Farts (My Body Science)*, Kane & Miller Publishers
Reading level: kindergarten to 6th grade
This title, which explores all forms of flatulence, is "both informative and blunt," said Publisher's Weekly. "The book provides young readers with solid facts as well as plenty to snicker about."

VOCABULARY

atom: the smallest particle still characterizing a chemical element

boiling: the transition from a liquid to a gas

chemoreception: the way the sense of smell works; the body's response to a chemical stimulus

condensing: the transition from a gas to a liquid; also from a gas to a solid

evaporation: the gradual transition of a liquid into a gas

freezing: the transition from a liquid to a solid

gas: a state of matter in which molecules move freely and interact only by random collisions; expands to uniformly fill its container

liquid: a state of matter in which molecules move relatively freely and fill their container

matter: anything that has mass and occupies space; stuff

melting: the transition from a solid to a liquid

molecule: a group of at least two atoms held together in a definite arrangement

pressure: continuous force applied by touching; created in a balloon by countless, tiny, high-speed gas molecules bouncing off the surface

solid: a state of matter in which atoms or molecules are closely and rigidly packed and resist changes in shape or volume

sublimation: the occasional transition of a solid directly into a gas without melting into a liquid first

Odors Aloft

SCIENTIFIC PROCEDURE

1. Take turns smelling each balloon. What do you think the balloons smell like? Write your ideas in the "Hypotheses" column.

2. Discuss your hypotheses with your group.

3. When you find out what is making the smell, write this information in the "Actual Smell" column.

Balloon Number	Hypotheses	Actual Smell

SUPPLY WORKSHEET

This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Odors Aloft

Recommended group size: 1–2

Number of Students: ☐ Number of Groups: ☐

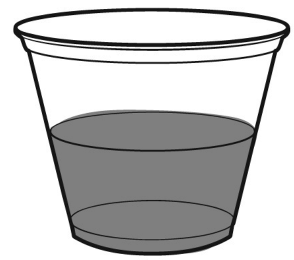
Supplies	Amount Needed	Supplies on Hand	Supplies Needed
balloons	1 per scent		
permanent marker	1 per teacher		
straw, pipette, or eyedropper	1 per teacher (eyedropper) **OR** 5–10 per teacher (disposable pipettes or straws)		
a selection of odor substances, for example: anise extract, vanilla extract, coffee extract (or very strong coffee), almond extract, peppermint extract, lemon extract, root beer concentrate, imitation chocolate flavor, imitation orange flavor, cinnamon, curry powder, ground cloves or clove oil, aftershave or perfume, baby lotion or baby powder, camphor- or eucalyptus-containing compound, e.g., Mentholatum or Vicks VapoRub Other nontoxic spices, extracts, or strong smelling substances with which the students may be familiar			
Extension A			
bottle of perfume or other strong smelling substance	1–2 per class		
Extension B			
plant material to extract scent from (citrus fruit peels, cinnamon sticks, vanilla pods, herbs, and flower petals all work well)	varies		
denatured alcohol (found in hardware stores)	enough to cover scent material in each jar		
sealable glass jars	1 per scent		
Teacher Demonstration			
no additional materials necessary			

Colores Kool

PROCEDIMIENTO CIENTÍFICO

1. Marca cuatro vasos con las palabras: "Frío," "Temperatura Ambiente," "Caliente," y "Sin Esponja de Acero."

2. Agrega 4 cucharadas de Kool-Aid **frío** en el vaso identificado como "Sin Esponja de Acero."
   - **Registra:** Escribe el sabor del Kool-Aid en la parte superior de la Tabla de Datos.
   - **Registra:** Escribe el color inicial del Kool-Aid en la Tabla de Datos.



3. Observa los pedazos de esponja de acero.
   - **Registra:** Describe cómo se ve la esponja de acero al principio del experimento. Escríbelo en la Tabla de Datos.

4. Agrega 4 cucharadas de Kool-Aid **frío** en el vaso identificado como "Frío."

5. Agrega un pedazo de esponja de acero en el vaso de Kool-Aid **frío**.
   - **Registra:** Escribe el color inicial del Kool-Aid frío.
   - **Registra:** Cada 30 segundos escribe el color del Kool-Aid en la Tabla de Datos.
   - Continúa por 5 minutos.

6. Agrega 4 cucharadas de Kool-Aid a **temperatura ambiente** en el vaso identificado como "Temperatura Ambiente".

7. Agrega un pedazo de esponja de acero en el vaso de Kool Aid **temperatura ambiente**.
   - **Registra:** Escribe el color inicial del Kool Aid a temperatura ambiente.
   - **Registra:** Cada 30 segundos escribe el color del Kool Aid en la Tabla de Datos.
   - Continúa por 5 minutos.

8. Agrega 4 cucharadas de Kool-Aid **caliente** en el vaso identificado como "Caliente."

9. Agrega un pedazo de esponja de acero en el vaso de Kool-Aid **caliente.**
   - **Registra:** Escribe el color inicial del Kool-Aid caliente.
   - **Registra:** Cada 30 segundos escribe el color del Kool-Aid en la Tabla de Datos.
   - Continúa por 5 minutos.

10. Saca la esponja de acero de todos los vasos.
    - ¿Cómo se ve la esponja de acero ahora?
    - **Registra:** Describe cómo se ve la esponja de acero al final del experimento. Escríbelo en la Tabla de Datos.

11. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

Colores Kool

TABLA de DATOS

Sabor del Kool-Aid Utilizado: ______________________________

	Tipos de Kool-Aid (Escribe el color de Kool-Aid abajo)		
Tiempo (minutos)	Kool-Aid Frío	Kool-Aid Temperatura Ambiente	Kool-Aid Caliente
Inicial (0:00)			
0:30			
1:00			
1:30			
2:00			
2:30			
3:00			
3:30			
4:00			
4:30			
5:00			

Esponja de acero	Apariencia Inicial	Apariencia Final
Escribe tus observaciones aquí →		

Globos Olorosos

PROCEDIMIENTO CIENTÍFICO

1. Tomen turnos para oler los globos. ¿A qué crees que huelen los globos? Escribe tus ideas en la columna de "Hipótesis."
2. Platica sobre tus hipótesis con tu grupo.
3. Cuando hayas descubierto de dónde viene el olor escríbelo en la columna de "Olor Real."

Número de globo	Hipótesis	Olor Real

Concepts

Chemicals naturally occur in our food. These chemicals can be used for testing household chemicals or making new chemicals.

Words to know

acid—a compound that increases the hydrogen ions (H^+) in a solution; often sour in taste.

base—a compound that increases the hydroxide ions (OH^-) in a solution; often bitter in taste.

chemical reaction—when two substances combine to create a new substance; often characterized by fizzing, color change, change in temperature, or creation of light.

dissolve—when the molecules of a solid separate and become completely surrounded by the molecules of a liquid.

hemoglobin—the molecule in red blood cells that enables them to carry oxygen.

indicator—a chemical that changes color with changes in pH.

metal—a substance that is often shiny, is able to be shaped, and conducts heat and electricity well.

molecule—a group of at least two atoms held together in a definite arrangement.

pH—a scale measuring relative acidity and basicity.

polymer—a large molecule that is made of many smaller molecules linked together.

solution—a completely uniform mixture.

soluble—the ability of a substance to dissolve in another substance.

Unscramble words from the Words to Know list to solve the double puzzle.

telma ☐☐☐☐◯

toisuonl ☐☐☐☐☐☐◯☐

voiselds ☐☐☐☐☐☐☐◯

bsae ☐☐☐◯

cadi ☐◯☐☐

loesulb ☐☐☐◯☐☐☐

plmoyre ☐☐◯☐☐☐☐

beohignmlo ☐☐◯☐☐☐☐☐☐☐

☐☐☐☐☐☐☐☐ ← Final Word

Circled letters:

1. Unscramble each of the clue words.
2. Write down each of the letters that appear in a circle in the box above.
3. Unscramble these letters to discover the final word.

OMSI

OREGON MUSEUM OF SCIENCE AND INDUSTRY

CheM LaB

Take-Home Activities

Food Chemistry

Spicy Indicator

Use turmeric to test for bases in your home!

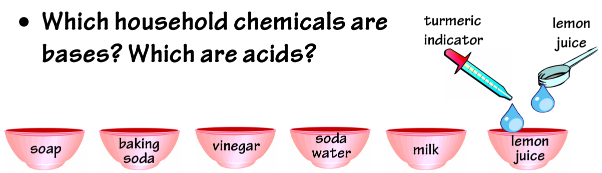
Materials:

¼ teaspoon turmeric powder
¼ cup rubbing (isopropyl) alcohol
one small jar with a tight-fitting lid
one eyedropper or small spoon
several small bowls or cups
household chemicals to test (for example: soap, household spray cleaner, window cleaner, ammonia, vinegar, baking soda, baking powder, milk, soda water, and lemon juice.)

To do and notice:

1. Combine the turmeric with the alcohol in the jar. Mix the two thoroughly. This is your indicator. (An indicator is a chemical that changes color with a change in pH (acidity/basicity).)
   - **What color is the turmeric-and-alcohol solution?**

2. In small bowls or cups, mix one teaspoon of each household chemical to be tested with a few drops of turmeric indicator. (You will be able to test only white or colorless substances.) Turmeric is yellow in an acid or neutral solution, but it turns red in a base.
   - **Which household chemicals are bases? Which are acids?**



A closer look:

The compound that creates the yellow color in turmeric will react with a base to form a red compound. Alcohol is used to prepare the indicator because turmeric is more soluble (dissolves better) in alcohol than in water.

Many soaps and household cleaners are bases. Baking soda is also a base, but baking powder has added ingredients that make it acidic.

Iron in Cereal

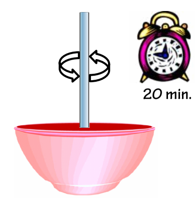
Find iron in your food!

Materials:

Total® brand cereal or other high-iron-content breakfast cereal
mixing bowl
water
plastic or glass rod
large spoon
magnets

To do and notice:

1. Place the entire box of cereal flakes into a large bowl. Use your hands to crush the flakes into small pieces.
2. Add enough water to the bowl to cover the flakes. Stir. As the flakes absorb water, add enough water to keep the mixture thin and soupy.
3. Tape a small magnet on the end of the rod.
4. Stir the cereal soup with the magnet for 20 minutes (take turns with a partner).
5. Remove the magnet from the cereal and observe. **What has collected on the magnet?**



A closer look:

As you stirred the cereal you dislodged small particles of the metal iron from the cereal flakes and these stuck to the magnet. These particles are so small that you do not notice them when you eat cereal.

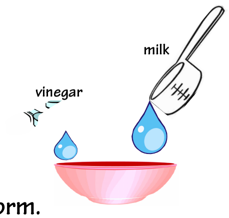
The human body requires iron for many functions including production of hemoglobin in red blood cells. Hemoglobin is the molecule that enables red blood cells to carry oxygen. The iron found in cereal (which is the same iron found in nails!) is converted by the acid in your stomach into a form that can be absorbed readily by your body.

Plastic Milk

You can make plastic from milk!

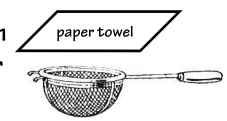
Materials:

½ cup milk
¼ cup vinegar
plastic tub (yogurt or margarine container)
old spoon or stick
paper towels
strainer
small plate

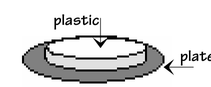


To do and notice:

1. Mix ½ cup milk and ¼ cup of vinegar together in the plastic tub. Stir the mixture until no more lumps (curds) form.
   - **What do the curds look like?**
2. Spread a paper towel over the bottom of the strainer, and place the strainer in the sink.



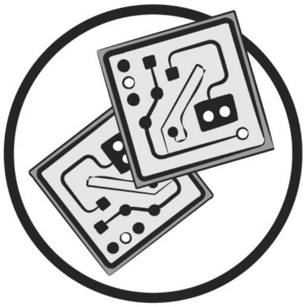
3. Pour the milk mixture through the strainer. Gently blot the curds with more paper towels to squeeze out any excess liquid.
4. Use your hands to squeeze the solid pieces together into a ball.
   - **What does the solid feel like?**
5. Pat the ball of solids into a disk and leave it on the plate to dry for one or two days. When it is completely dry, pick it up.
   - **What does it feel like now?**



A closer look:

You have just made a type of plastic using milk protein. Casein is a protein found in milk The vinegar (an acid) made the casein molecules in the milk cling together to form curds. By drying out these curds, you obtained a hard material, called a **polymer**, made of many molecules linked together.

Casein is a common ingredient in food. It is also used in the manufacture of paint, white glue, and paper.



Choose Your Ooze

Learning Objectives: *Students learn how changing ingredients in a recipe affects the results.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Physical Properties
Chemical Reactions
Industrial Chemistry

PROCESS SKILLS

Comparing and Contrasting
Predicting
Classifying
Inferring

GROUP SIZE

2–3

SNEAK PEAK inside …

ACTIVITY

Students mix white glue and detergent in various proportions to make different versions of ooze.

STUDENT SUPPLIES

see next page for more supplies

white glue
Borax detergent
Staflo starch
paper cups
craft sticks, etc.…

ADVANCE PREPARATION

see next page for more details

Make Borax solution
Make starch solution, etc.…

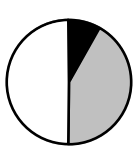
OPTIONAL EXTRAS

DEMONSTRATION
Polymer Games (p. F - 7)

EXTENSIONS
Evaluate Your Ooze (p. F - 13)
Ooze Invention Convention (p. F - 13)

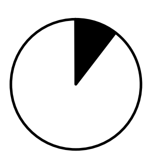
TIME REQUIRED

Advance Preparation



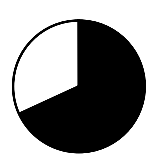
5 min (procedure A or B)
30 min (procedure C)

Set Up



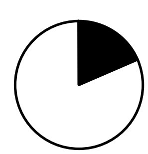
5 minutes

Activity



40 minutes

Clean Up



10 minutes

SUPPLIES

There are three different suggestions for how to run the activity:

- **Procedure A—**Best for young students. Students investigate and compare the properties of two different ooze recipes, Flubber and Glarch. (See p. F - 16.)
- **Procedure B—**Older students recommended. Students make Glarch. Then they repeat the experiment by using different ratios of ingredients. Students compare the resulting oozes and make inferences about how different ratios of ingredients affect the result. (See p. F - 17.)
- **Procedure C—**Older students recommended. Students make many ooze recipes by substituting different solutions. Students should compare the different resulting oozes and make inferences about how each ingredient affects the result. (See p. F - 18 to p. F -21.)

Item	Amount Needed
Procedure A	
liquid white glue (e.g., Elmer's™)	1 bottle (4 oz.) per group
Borax™ detergent	1 teaspoon per class
water	2¼ cups per class
Stāflo™ liquid starch	¼ cup per group
Procedure B	
liquid white glue (e.g., Elmer's)	1 bottle (4 oz.) per group
Stāflo liquid starch	½ cup per group
Procedure C	
white glue (e.g., Elmer's)	1 bottle (4 oz.) per group
Borax detergent	1 teaspoon per class
water	4½ cups per class
Stāflo liquid starch	¼ cup per group
liquid clear glue (e.g., Elmer's)	1 bottle (4 oz.) per group
cornstarch	¼ cup per class
General Supplies	
Pop-top squeeze bottles (e.g., water or sport drink) for distributing solutions	1–4 per group (see Set Up notes)
plastic spoons	2 per group
wooden craft sticks **and** wax paper cups (e.g., Dixie™), 4 oz. for mixing **OR** sealing plastic bags (e.g., Ziploc™) snack size	3–5 per group
vinegar (for clean up)	2 cups per class
cafeteria trays	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Note:
Before you start to make solutions, decide which procedure you will follow. Then, have the procedure sheet in hand to help you understand which solutions you need to make.

Borax Solution (for Procedures A and C):

- Borax detergent is normally sold under the name 20 Mule Team Borax and found in the detergent section of the grocery store. Look for the ingredient "sodium tetraborate."
- Measure 2¼ cups of water. Add a scant teaspoon of Borax detergent and mix well.
- Fill pop-top squeeze bottles with ¼ cup of Borax solution.
- Label the bottles "Borax Solution."

Stāflo Solution (for Procedures A, B, and C):

- Stāflo liquid starch solution is found in the detergent section of the grocery store. Look for the ingredients "starch" and "Borax " or "sodium tetraborate."
- Fill pop-top squeeze bottles with ¼ cup of Stāflo solution.
- Label the bottles "Stāflo Solution."

Starch Solution (for Procedure C):

- Use this solution as a substitute for Stāflo liquid starch in the ooze recipe.
- This solution is a little tricky. About the same difficulty as making a smooth gravy. Read all directions before making the solution.
- Heat 4 cups of water to boiling. Lower the heat to keep the water just below boiling.
- In a separate container, mix ¼ cup cornstarch with ½ cup of water. Stir this solution to mix completely.
- While stirring the boiling water constantly, <u>slowly</u> add the starch mixture to the hot water.
- Continue to heat and constantly stir the solution until it is translucent, about 5 to 10 minutes.
- Remove the solution from the heat and allow it to cool to room temperature.
- Bacteria will grow in the starch solution unless it is refrigerated. It should last about a week in the refrigerator. Store this solution in the refrigerator until use.
- When you are ready for the activity, fill pop-top squeeze bottles with about ¼ cup starch solution.
- Label the bottles "Starch Solution."

Teacher's Secret Solution (for Procedure C):

- This solution is made from water, Borax, and starch so is a generic form of Stāflo.
- Use this solution as a substitute for Stāflo liquid starch in the ooze recipe.
- Measure 2 ¼ cups of starch solution (above). Add a scant teaspoon of Borax detergent and mix well.
- Bacteria may grow in the Secret Solution unless it is refrigerated. It should last about a week in the refrigerator. Store this solution in the refrigerator until use.
- When you are ready for the activity, fill pop-top squeeze bottles with about ¼ cup Secret Solution.
- Label the bottles using your name and "Secret Solution."

Notes and Hints

- Give each group a cafeteria tray to do their experiments on. This keeps spills and messes contained.
- To further contain messes, use sealable plastic bags to mix the ooze ingredients. For procedures B and C, paper cups and craft sticks are a cheaper option.

SETUP

<u>Procedure A</u>

<u>For each group</u>

- 1 bottle of white glue
- Borax solution in pop-top squeeze bottle
- Stāflo liquid starch in pop-top squeeze bottle
- plastic spoons
- cafeteria tray
- **Either** wooden craft sticks and wax paper cups
  Or sealable plastic bags

<u>At a central location (or with the teacher)</u>

- vinegar
- towels and sponges for clean up

<u>Procedure B</u>

<u>For each group</u>

- ❑ 1 bottle of white glue
- ❑ Stāflo liquid starch in pop-top squeeze bottle
- ❑ plastic spoons
- ❑ cafeteria tray
- ❑ **Either** wooden craft sticks and wax paper cups
  Or sealable plastic bags

<u>At a central location (or with the teacher)</u>

- ❑ vinegar
- ❑ towels and sponges for clean up

<u>Procedure C</u>

<u>For each group</u>

- ❑ 1 bottle of white glue
- ❑ 1 bottle of clear glue
- ❑ Borax solution in pop-top squeeze bottle
- ❑ Stāflo liquid starch in pop-top squeeze bottle
- ❑ starch solution in pop-top squeeze bottle
- ❑ imitation Stāflo solution in pop-top squeeze bottle
- ❑ plastic spoons
- ❑ cafeteria tray
- ❑ **Either** wooden craft sticks and wax paper cups
  Or sealable plastic bags

<u>At a central location (or with the teacher)</u>

- ❑ vinegar
- ❑ towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

Depending on what procedure you choose for your class, you may need to introduce the activity differently. All procedures focus on comparing the properties of oozes from different recipes. These questions focus on properties students can evalauate.

No matter what procedure you choose, take time to discuss with students why the experiment is designed the way it is. Each procedure uses different recipes, and students should compare the ingredients and infer how the recipe results in different ooze properties.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

What are some things you know that are solid? What are the properties of a solid?
Rocks, desks, gold. They are hard, they don't change shape, they have a fixed volume.

What are some liquids you know? What are the properties of a liquid?
Water, juice, milk, oil, syrup. They change shape to fit in a container, they have a fixed volume.

Can you think of some things that act like a solid and a liquid or seem to be somewhere in between?
Clay, silly putty, play-doh, toothpaste, peanut butter.
What properties do these materials have?
These all keep their shape to some extent but also can flow like a liquid. Some will stretch, but some will break. After breaking apart, they will re-form together. Some will bounce.

In this activity, students will create different mixtures that have properties of both a liquid and a solid. They will investigate the characteristics of oozes made from different ingredients.

Polymer Games
This works well to introduce students to the activity. Students model long glue molecules that become ooze when Borax solution is added.

Supplies
- large open area
- 4–6 pieces of elastic or rubber tubing, each about 2 yards long and each tied into a loop

Demonstration
- Divide the students into three groups. Each group should make a long line of students holding hands. Each line of students represents a glue molecule.
- Glue molecules are called **polymers**. A polymer is a long molecule made of repeating smaller molecules.
- Instruct the students to keep holding hands and to move their molecules around the room and around each other. This is the liquid glue they use in the activity.
- Introduce the loops of elastic or tubing. These are molecules of sodium borate, the active ingredient in Borax detergent.
- Two students should step into each loop of elastic or tubing. Preferably, two students are from different glue molecules. The glue molecules have now been **cross-linked** together by the sodium borate.
- Instruct the students to move their molecules again. They should try to pull apart the molecules without breaking free of the elastic. This is the ooze they create in the activity.

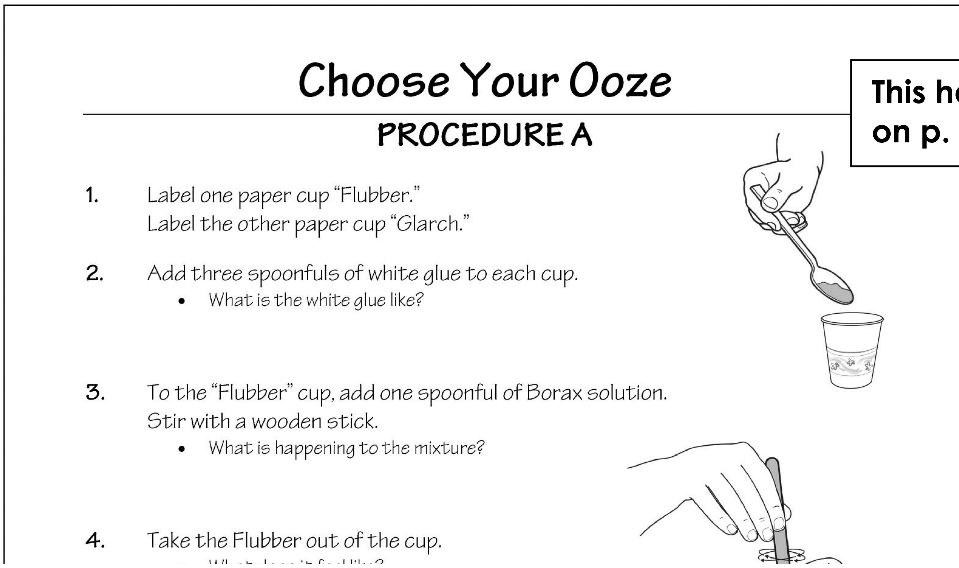
Explanation

Glue molecules are long chains of molecules known as polymers. The sodium borate in the Borax solution cross-links the polymers together. This creates a network of glue molecules that act like an ooze—sharing some properties of a solid and some like a liquid. When the glue molecules are cross-linked, they can still slide past each other, but it is more difficult.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure of your choice.
Procedure A on p F - 16, Procedure B on p. F - 17, Procedure C on p. F - 18 to F - 21.
Below are suggestions to help the teacher facilitate the activity.

NOTES



Choose Your Ooze

PROCEDURE A

1. Label one paper cup "Flubber."
   Label the other paper cup "Glarch."
2. Add three spoonfuls of white glue to each cup.
   - What is the white glue like?
3. To the "Flubber" cup, add one spoonful of Borax solution.
   Stir with a wooden stick.
   - What is happening to the mixture?
4. Take the Flubber out of the cup.

This handout is on p. F - 16.

This activity features recipes for two different oozes, Flubber and Glarch. In Procedure A, students make these basic recipes and compare the results. In Procedures B and C they also make variations to the recipes to create different oozes.

You may want to instruct students to write their answers on a separate sheet of paper so they will have more space to write.

Running Suggestions

- This activity can get very messy very quickly. Ideas to minimize the mess include:
  - Each group should experiment on a cafeteria tray and keep all their materials on the tray.
  - Mixing the oozes in sealable bags contains the mess well and also provides a container for students to take their ooze home. However, it can be expensive.
  - Vinegar dissolves all forms of ooze made in this activity.
- Students can use any sized spoon to add the ingredients to the cups. The exact amount does not matter as long as the same sized spoon is used for all the solutions.

- **Procedure B:** The last recipe uses 8 spoonfuls of glue and 2 spoonfuls of Stāflo liquid starch. This volume is a bit large and may require a slightly larger cup.
- **Procedure C:** Introduce your "Special Solution." Explain to students that your solution is just like the name brand Stāflo liquid starch, but without the fragrance or conditioners.

Ongoing Assessment

- Does the ooze stay the same as you continue to work with it? How do its properties change? *(As the Borax continues to react with the glue, the ooze becomes firmer and less sticky. It also may become less stretchy.)*
- Which ooze do you like best? Why? What are the properties of a good ooze?

Safety and Disposal

- All materials may be thrown in the trash.
- Students may take their ooze home in a plastic bag if they wish. All the ooze can be mixed together into a large airtight container and stored for up to a month.
- Vinegar dissolves ooze from carpet, clothing, hair, and other materials.

CAUTION: Do not allow any ooze to be placed in the sink. It will clog the drains.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

After experimenting with different recipes, invite the students to report on their findings.

How did you investigate the oozes that you made?
Pulled them apart quickly to see if they would break. Pulled them slowly to see if they would stretch. Smashed them to see how sticky they were. After they broke apart, pushed them to see if they would go back together. Left it on the counter to see if it would hold its shape. Dropped it on the table to see if it would bounce.

Which ooze was your favorite? Why?
Answers will vary. Extension A provides some categories for students to use to evaluate their ooze recipes.

EXPLANATION

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

This activity features recipes for two different oozes, Flubber and Glarch. In Procedure A, students make these basic recipes and compare the results. In Procedures B and C they also make variations to the recipes to create different oozes.

BACKGROUND FOR ALL GRADES

Flubber Basics
The ingredients for Flubber are white glue, water, and Borax. Each of these three ingredients serves a different purpose. Together, they interact to make an interesting substance. Depending on the ratio of ingredients, the Flubber created can be very slimy, sticky, and stretchy, or it can be very firm, smooth, and brittle.

Properties of Glue
Both white glue and clear glue are made from the same kinds of **molecules.** One molecule of glue will be a chain of 4000 to 6000 carbon **atoms**. (Connected to this chain are other oxygen and hydrogen atoms.) These molecules are **polymers** because they are made of repeating smaller units. When these glue polymers are dissolved in water, the molecules slide past each other and act as a liquid.

Borax Detergent and the Creation of Flubber
When students add Borax solution to the glue, the mixture begins to stiffen. In this situation, Borax is a **cross-linking** agent. Each molecule in the Borax solution reacts with two different glue molecules, linking them together. Just like in the Teacher Demonstration, the cross-linked glue molecules cannot slide past each other as easily.

As the Borax continues to react with the glue, the glue molecules become increasingly connected, or cross-linked. Over time, the Flubber will become firmer and not stretch as easily.

When students pull the Flubber slowly, the molecules are able to slide past each other, and the Flubber stretches. When students pull the Flubber quickly, the cross-linked molecules cannot slide as easily and the Flubber breaks apart.

Add Starch to Make Glarch
The standard Glarch recipe uses white glue and Stāflo liquid starch. Stāflo contains water, Borax, and starch, so the only difference between Flubber and Glarch is the addition of starch to the mix. Students should notice that Glarch is easier to stretch than Flubber. Even when Glarch is pulled quickly, it tends to stretch instead of break.

Starch is also a polymer. Long molecules of starch are made of smaller sugar molecules linked together. The long starch molecules do not cross-link to the glue molecules or to the molecules in Borax solution. Instead, the starch molecules weave themselves in the cross-linked network of glue and Borax. These starch molecules slide past each other and help the cross-linked glue molecules to also slide. Thus, Glarch is stretched more easily than Flubber.

Experimental Design

Chemists often need to find out what ingredients in a mixture are causing a certain **chemical reaction**. To do this they need to test each ingredient of the mixture separately. Chemists can either separate out each of the ingredients of the mixture and test them individually, or they can carry out their tests while changing only one variable at a time.

In Procedure A, students compare two recipes to find what happens when an ingredient (Borax solution) is replaced with another (Stāflo liquid starch). By keeping the amounts of ingredients the same, they can be sure that any difference in the results can be attributed to this substitution.

In Procedure B, students use the same recipe but alter the ratios of ingredients. By keeping the amount of glue the same and changing only the amount of Stāflo liquid starch, they can see what affect the Stāflo has on the properties of Glarch. As more Stāflo is added, students should notice that the Glarch increases in its ability to stretch.

In Procedure C, students conduct a variety of experiments to understand what role each component of Flubber and Glarch plays in the reaction.

- When students substitute clear glue in both recipes, they should see that the resulting oozes do not stretch as easily as when they are made with white glue. Since this happens for both Flubber and Glarch, students should understand that the type of glue is important for deciding the amount of "stretchy-ness."
- When students substitute different solutions in the recipe for Glarch, students should notice that some combinations result in making an ooze, and some do not.
    - The teacher's Special Solution works just as well as Stāflo. This shows that there are "extra" ingredients in regular Stāflo that are not necessary for the reaction.
    - Starch by itself <u>does not</u> create a new substance. This shows that the starch and glue are not reacting to one another.
    - Borax by itself <u>does</u> create a new substance. This shows that Borax is a necessary ingredient and creates the cross-linked network.
    - When students compare the results of adding Borax by itself to the results from adding Stāflo and the Secret Solution, they should see that adding Borax alone makes a firmer ooze. Starch makes the resulting ooze stretch more easily.
    - Finally, because Stāflo and the Secret Solution are both still liquids, this shows that the Borax and starch do not react with one another.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

BACKGROUND FOR OLDER STUDENTS

Molecules of Ooze

White glue and clear glue are polymers made from repeating units of vinyl acetate (see Figure 1). So another name for these glues is **polyvinyl acetate**. The acetate parts stick out of the long chain of the molecule so are available to react.

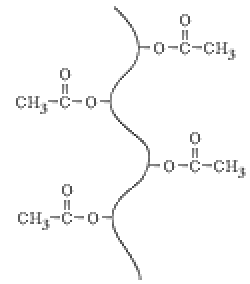


Figure 1 A long molecule of glue is made of smaller units of vinyl acetate.

Borax detergent has the chemical name **sodium tetraborate** (NaB_4O_7). In water, the molecules of sodium tetraborate separate into sodium (Na^+) and borate $B(OH)_4^-$ ions. The borate ion is formed like a large letter "X" with a boron atom in the center and four oxygen and hydrogen groups (–OH groups) extending from it.

The borate ion is reactive and connects two different glue molecules. The –OH groups on the borate ion connect to acetate groups in the glue molecule. When this reaction happens across two glue molecules, the glue becomes cross-linked, and the glue molecules cannot slide past each other as easily. This makes the liquid glue change from an easily flowing liquid to a stiff ooze.

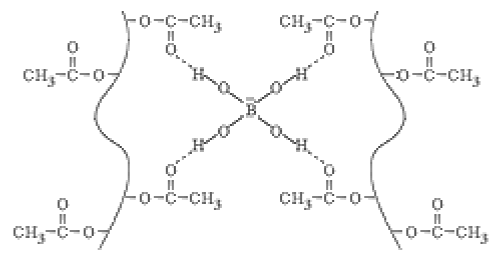


Figure 2 The borate ion cross-links two glue molecules.

Hydrogen Bonds Make it Stretchy

When oxygen is bonded to another atom, the electrons between oxygen and the other atom are not shared equally. Oxygen has a greater hold on the electrons. This makes the oxygen have a small negative charge, and the other atom have a small positive charge. For this reason, the bond between oxygen and its partner is called a **polar bond**.

For more information about polar bonds, see the Explanation section of **Salting Out**.

In acetate, oxygen is doubly bonded to carbon, so oxygen has a small negative charge and the carbon has a small positive charge. In every –OH group, the oxygen has a small negative charge and the hydrogen has a small positive charge.

The small charges on one polar bond attract the small charges on another polar bond. This attraction helps the glue molecules stay attracted to each other and slide past each other. The attraction of –OH groups to one another or to other polar bonds is called **hydrogen bonding**. (Even though oxygen is a necessary player, it doesn't seem to get credit for this attractive force.)

When borate ions $B(OH)_4^-$ react with glue, they decrease the amount of hydrogen bonding available. When Flubber is pulled apart slowly, there is still enough hydrogen bonding to allow the molecules to stay attracted, and the Flubber stretches. When the Flubber is pulled quickly, the hydrogen bonding is not enough to keep the molecules attracted, and the Flubber breaks.

Add Starch to Make Glarch, part 2
Starch is also a polymer. Long molecules of starch are made of smaller sugar molecules linked together. (See Figure 3.) Sugar molecules have many –OH bonds and contribute a lot of hydrogen bonding. When the starch molecules interweave with the molecules in Glarch, they increase the amount of hydrogen bonding available. This is why Glarch is able to remain intact even when it is stretched very quickly.

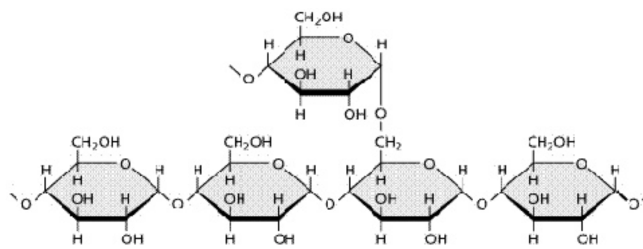


Figure 3. Each sugar molecule is a ring with many –OH groups extending from it. Many sugar molecules (networks of 100's) link together to form starch.

EXTENSIONS

Extension A: Evaluate Your Ooze
Now that students have made different recipes of ooze, they probably have an opinion of which they prefer. Use a ranking system to evaluate and judge the different ooze recipes.

Extra Instructions
- As a class, define categories to judge the characteristics of ooze. For instance, stretchiness, stickiness, bounciness, ability to retain its shape.
- After defining different categories, students can rank each ooze in all the categories.

Extension B: Ooze Invention Convention
Be truly adventurous and allow students to create their own ooze recipe. Supply them with all the ingredients given for Procedure C. Instruct students to keep careful track of their ingredients and formulas for their own ooze creations. You may wish to supply them with measuring spoons for more accurate recipes and records.

CROSS-CURRICULAR CONNECTIONS

LANGUAGE ARTS

Ooze Brochures

Give the students supplies to make posters, brochures, or other advertising to convince people to buy their brand of ooze. They should come up with a good name for their product, and state all its properties.

Oobleck

Another ooze, Oobleck was made famous by the story *Bartholomew and the Oobleck* by Dr. Seuss. Read the book in your class, then make Oobleck by mixing 1 cup of cornstarch with ½ cup of water. This mixture is a suspension of solids in a liquid and has unusual properties. When a great force is applied, it acts like a solid—you can even walk on it. When little force is applied, it acts like a liquid—it will run through your fingers.

COOKING

Recipe Substitutions

Make cookies, muffins, or bread but eliminate some of the ingredients. What happens if you don't put in sugar? What if you don't put in baking soda? What if you use milk instead of eggs? By eliminating, substituting, or changing the proportions of ingredients, students can find out the purpose of each ingredient in a recipe.

RESOURCES

Web – http://www.omsi.edu/flubber
The official OMSI recipe for making Flubber.

Web – http://www.chemheritage.org/educationalservices/faces/poly/activity/resin.htm
This Web site contains specific chemical information about the reaction between Borax and glue. Gives more suggestions for making Flubber, which is called Glüg in the site. The images of the polyvinyl acetate and the cross-linked polyvinyl acetate and borate ions come from this site.

Web – http://www.youtube.com/watch?v=fazPiaHvFcg
This video, "Kid Science Episode 1: Cornstarch Suspension" is one of the favorites in the Chemistry Lab at OMSI. The host, Blake (age ~9), makes a suspension of cornstarch in water and explores some of its properties. He also discusses the three types of matter. We eagerly wait for future episodes from this young scientist.

Web – http://www.youtube.com/watch?v=yHIAcASsf6U
This video titled "People Run on a Pool of Oobleck" shows two men running across a suspension of cornstarch in water. The pool is about 3 feet deep, and you can see how the suspension compresses under their weight under high force. This video is not in English but still quite entertaining.

Dr. Seuss, *Bartholomew and the Oobleck*
Reading level: kindergarten to 4th grade
This is a sequel to The 500 Hats of Bartholomew Cubbins, a page to King Derwin in the kingdom of Didd. King Derwin orders something more interesting to fall from the sky and gets Oobleck, a sticky, green substance. Discusses the importance of owning up to your mistakes.

VOCABULARY

cross-link: to connect many molecules together in multiple places creating a large network of molecules

hydrogen bonds: attractive forces between molecules that each have a hydrogen and oxygen bound together (–OH group) and extending from the molecule

liquid: a state of matter in which atoms or molecules move relatively freely and fill their container

molecule: a group of at least two atoms held together in a definite arrangement

polar bond: connections between atoms where the electrons are not equally shared; molecules with these bonds tend to have a small electrical charge

polymer: a large molecule made of many repeated molecules

polyvinyl acetate: the active ingredient in liquid white glue and liquid clear glue

sodium tetraborate: the active ingredient in Borax detergent

solid: a state of matter in which atoms or molecules are closely and rigidly packed and resist changes in shape or volume

starch: long chains of sugar molecules; plants create this molecule as a way to store energy

.

Choose Your Ooze

PROCEDURE A

1. Label one paper cup "Flubber."
    - Label the other paper cup "Glarch."

2. Add three spoonfuls of white glue to each cup.
    - What is the white glue like?

3. To the "Flubber" cup, add one spoonful of Borax solution. Stir with a wooden stick.
    - What is happening to the mixture?

4. Take the Flubber out of the cup.
    - What does it feel like?
    - Does it bounce?
    - Does it stretch?

5. To the "Glarch" cup, add one spoonful of Staflo solution. Stir with a wooden stick.
    - What is happening to the mixture?

6. Take the Glarch out of the cup.
    - What does it feel like?
    - Does it bounce?
    - Does it stretch?

7. Clean up your area.
    - Follow your teacher's directions.

Choose Your Ooze

PROCEDURE B

1. Label five paper cups #1 to #5.
2. Add white glue to each cup according to the chart.
3. To cup#1, add two spoonfuls of Staflo solution.
   - Stir with a wooden stick.
   - What is happening to the mixture?
   - Write your answer in the data table.

4. *Take the ooze out of the cup.*
   - *What does it feel like? Does it bounce? Does it stretch?*
   - *Write your observations in the table.*
5. Repeat steps 3 and 4 for the rest of the cups.
   - *What properties of the ooze change as the amount of glue changes?*
6. Clean up your area
   - *Follow your teacher's directions.*

cup	1	2	3	4	5
white glue	4 spoonfuls	5 spoonfuls	6 spoonfuls	7 spoonfuls	8 spoonfuls
Staflo	2 spoonfuls	2 spoonfuls	2 spoonfuls	2 spoonfuls	2 spoonfuls
notes					

Choose Your Ooze

PROCEDURE C

Glue Substitution in Flubber

1. Label two cups "Flubber" and "Clear Flubber."

2. Add white glue or clear glue to each cup according to the table.

	glue	Borax	notes
Flubber	3 spoonfuls white glue	1 spoonful	
Clear Flubber	3 spoonfuls clear glue	1 spoonful	

3. To the "Flubber" and "Clear Flubber" cups, add 1 spoonful of Borax solution.

4. Stir with a wooden stick.
   - What is happening to each mixture?
   - Write your answer in the table.

5. Take the two kinds of Flubber out of the cups.
   - What do they feel like? Do they bounce? Do they stretch?
   - Write your answers in the table.

6. Compare the properties of Flubber and Clear Flubber.
   - How are they the same?

   - How are they different?

7. Clean up your area.
   - Follow your teacher's directions.

Choose Your Ooze

PROCEDURE C

Glue Substitution in Glarch

1. Label two paper cups "Glarch" and "Clear Glarch."

2. Add white glue or clear glue to each cup according to the table.

	glue	Staflo	notes
Glarch	3 spoonfuls white glue	1 spoonful	
Clear Glarch	3 spoonfuls clear glue	1 spoonful	

3. To the "Glarch" and "Clear Glarch" cups, add 1 spoonful of Staflo.

4. Stir with a wooden stick.
    - What is happening to each mixture?
    - Write your answer in the table.

5. Take the two kinds of Glarch out of the cups.
    - What do they feel like? Do they bounce? Do they stretch?
    - Write your answers in the table.

6. Compare the properties of Glarch and Clear Glarch.
    - How are they the same?
    - How are they different?

7. Clean up your area.
    - Follow your teacher's directions.

Choose Your Ooze

PROCEDURE C

Staflo Substitution in Glarch

1. Label four paper cups from #1 to #4.
2. Add 3 spoonfuls of white glue to each cup.
3. To cup#1, add one spoonful of Staflo solution.
   - Stir with a wooden stick.
   - What is happening to the mixture?
   - Write your answer in the data table.

4. Take the ooze out of the cup.
   - What does it feel like? Does it bounce? Does it stretch?
   - Write your observations in the table.
5. Repeat steps 3 and 4 for the other cups.
   - Substitute a different solution for Staflo in each cup according to the table.
6. Compare all the different versions of Glarch.
   - Can you use a "Secret Solution" to make Glarch?
   - **Explain:** How do you know?

   - Which makes the glue turn into ooze—starch or Borax?
   - **Explain:** How do you know?

   - What property does starch create in the ooze?
   - **Explain:** How do you know?

   - **Choose your ooze:** Which recipe of Glarch to you like best?
   - **Explain:** Why is this choice the best?

7. Clean up your area.
   - Follow your teacher's directions.

Choose Your Ooze

PROCEDURE C—DATA TABLE

Staflo Substitution in Glarch

	1	2	3	4
	Glarch	Secret Solution Glarch	Glarch, no Borax	Glarch, no starch (Flubber)
glue	3 spoonfuls white glue	3 spoonfuls white glue	3 spoonfuls white glue	3 spoonfuls white glue
Staflo	1 spoonful			
Secret Solution		1 spoonful		
starch			1 spoonful	
Borax				1 spoonful
notes				

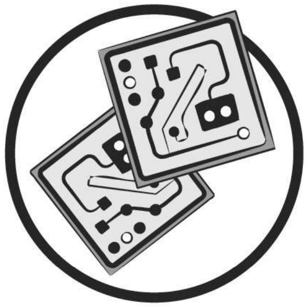
This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Choose Your Ooze

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Procedure A			
white glue (e.g., Elmer's™)	1 bottle (4 oz.) per group		
Borax™ detergent	1 teaspoon per class		
water	2¼ cups per class		
Stāflo™ liquid starch	¼ cup per group		
Procedure B			
white glue (e.g., Elmer's™)	1 bottle (4 oz.) per group		
Stāflo™ liquid starch	½ cup per group		
Procedure C			
white glue (e.g., Elmer's™)	1 bottle (4 oz.) per group		
Borax™ detergent	1 teaspoon per class		
water	4½ cups per class		
Stāflo™ liquid starch	¼ cup per group		
clear glue (e.g., Elmer's™)	1 bottle (4 oz.) per group		
cornstarch	¼ cup per class		
General Supplies			
Pop-top squeeze bottles (e.g., water or sport drink) for distributing solutions	1–4 per group (see Set Up notes)		
plastic spoons	2 per group		
wooden sticks **and** wax paper cups (e.g., Dixie™) (4 oz.) for mixing **OR** resealing plastic bags (e.g., Ziploc™) snack size	3–5 per group		
vinegar (for clean up)	2 cups per class		
cafeteria trays	1 per group		
Extension A			
no extra supplies needed			
Extension B			
same as Procedure C			
Teacher Demonstration			
elastic or rubber tubing, each about 2 yards long and each tied into a loop	4–6 pieces per class		



Penny for Your Thoughts

Learning Objectives: *Students learn how metals react with each other.*

GRADE LEVEL

3–8

SCIENCE TOPICS

Atoms and Molecules
Chemical Reactions
Industrial Chemistry

PROCESS SKILLS

Comparing/Contrasting
Predicting
Analyzing

GROUP SIZE

2–3

SNEAK PEAK inside …

ACTIVITY

Students copper plate metal objects by placing them in a jar with pennies, vinegar, and salt.

STUDENT SUPPLIES

see next page for more supplies

small jars with lids (e.g., baby food jars)
vinegar, salt
pennies (pre-1983 work best)
steel paperclips, etc.…

ADVANCE PREPARATION

see next page for more details

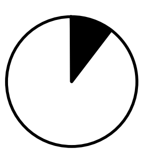
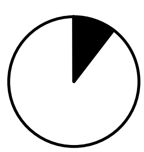
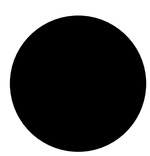
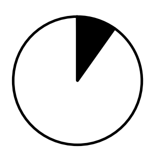
Fill pop-top bottles with vinegar
Set out cups of salt, etc.…

OPTIONAL EXTRAS

DEMONSTRATION
Copper Corrosion (p. F - 26)

EXTENSIONS
Inquiry Opportunity—Substitute Ingredients (p. F - 31)
Electroplating (p. F - 31)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
5 minutes	**5 minutes**	**30–90 minutes waiting for reaction**	**5 minutes**

SUPPLIES

Item	Amount Needed
small jars with lids (baby food jars work well)	1 per group
vinegar	½ cup per group
pop-top squeeze bottles (e.g., water or sports drink)	1 per group
salt	2 spoonfuls per group
steel paperclips (or other small iron-containing objects)	3–4 per group
pennies (must be pre-1983)	15 per group
plastic spoons	1 per group
plastic cups, any size	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation
Vinegar:

- Fill pop-top squeeze bottles with about ½ cup vinegar.
- Label the bottle "vinegar."

Salt:

- Fill plastic cups with 2 spoonfuls of salt.
- Label these cups "salt."

Notes and Hints

- Pennies made before 1983 have higher copper content and work better in this activity. Encourage students to collect pennies for a few weeks prior to starting this activity.
- Try to use paperclips that do not say "smooth finish." Smooth finish paperclips have a coating that turns gray instead of copper. To make sure paperclips work well, it is a good idea to test out the experiment the night before.
- Other small steel objects, such as nails, also work. If you use nails, caution students appropriately. Stainless steel objects (spoons, etc.) will not work, as they are specially formulated to resist this kind of reaction.

SETUP

For each group
- jar with lid
- 15 pennies (pre-1983)
- 3–4 paperclips
- vinegar in pop-top squeeze bottle
- salt in plastic cups
- spoon

At a central location (or with the teacher)
- towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will conduct a reaction between two metals—copper in pennies and iron in paperclips.

Are metals permanent? Can two metals react with each other?
Metals are not permanent; they can dissolve into solution or they can corrode. One example of a metal corroding is rust. If you leave a nail outside, the iron molecules will react with the oxygen and the water in the air to create iron oxide. Also some iron will dissolve in rainwater, causing the nail to weaken.

When a metal reacts or corrodes, where did those metal atoms go? Can you get them back?
When you leave a piece of metal in solution, bits of the metal break off and dissolve into the solution. These bits stay in solution unless you also have another, more reactive metal in the solution. When this happens, the molecules will travel from one metal and stick (or plate) onto the other.

Are all chemicals equally reactive? How are they different?
Some chemicals react more readily than others. Iron is very reactive, that is why you see it rust a lot. Gold is very unreactive, this is why you never see "rusted" gold.

Some metal things are made of layers of metals. Can you think of some examples? Why would you want to layer one metal on another?
Jewelry would be very expensive if it were pure gold, so many gold items are only covered with a thin layer of gold. Also, gold is very soft, so mixing gold with other metals can make it stronger.

A penny requires more than one cent's worth of copper, so pennies are only coated with copper and have a zinc core. Also, some metals corrode or rust very easily. By coating one metal that is less reactive on top, it protects the metal underneath.

In this activity, students will have the opportunity to plate metal objects with copper.

TEACHER DEMONSTRATION

Copper Corrosion
Teachers can demonstrate corrosion using copper coated steel BBs and bleach.

Since the activity takes some time, set up the experiment with students first. Then do this demonstration while you are waiting for the pennies and paperclips to react.

Supplies
- glass cup
- overhead projector
- about 50 (about 1 tablespoon) copper coated steel BBs (available at sporting goods stores)
- full strength bleach (enough to cover BBs in the cup)
- disposable gloves

CAUTION: Bleach is poisonous and hazardous to eyes, skin, and the respiratory tract. Handle with caution. Never mix bleach with other household cleaners, as it may release toxic gases. Wear gloves and use care when handling.

Demonstration

- Place about 50 copper BBs in a glass cup. While wearing gloves, immerse BBs in bleach solution and place on projector.
- Depending on how new/strong the bleach is, the BBs will start rusting anywhere from a few seconds to a few minutes after immersion. With very new bleach, the solution may heat up or bubble as well.
- Red-brown flakes will form on the BBs; some will come off and float in the solution.

Explanation

Bleach is very reactive and gives away oxygen very easily. This oxygen reacts with the copper almost instantly, creating copper oxide. This is similar to the reaction seen on iron when iron rusts. The substance we call "rust" is actually iron oxide.

In this reaction, the copper from the BBs dissolves in the bleach. Then it reacts with the oxygen to form copper oxide. The copper oxide is not able to dissolve in the bleach, so it forms a red-brown solid.

Have students follow the Scientific Procedure on page F-34, working in groups of 2–3 Below are suggestions to help the teacher facilitate the activity.

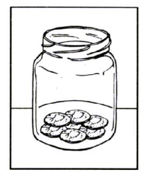
NOTES

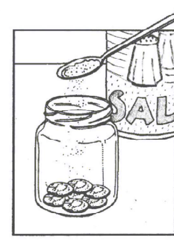
Penny for Your Thoughts

SCIENTIFIC PROCEDURE

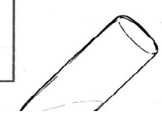
This handout is on p. F - 34.

1. Label a jar with your name(s).
2. Put fifteen pennies in the jar.
   - *What do the pennies look like?*





3. Add 2 spoonfuls of salt into the jar.
4. Fill the jar halfway with vinegar.
   - *What does the salt and vinegar mixture look like?*



Running Suggestions

- The reaction between the pennies and paperclips takes at least fifteen minutes before any change is obvious. Use this time to perform the teacher demonstration (corrosion of copper BBs in bleach, a fast and easily observed color changing reaction).
- Alternatively, use the time to explore vocabulary terms during this time, write down student hypotheses, or explore a cross-curricular connection.
- You may choose to do this activity at the beginning of the day and then revisit it periodically through the day. Or students can set up the experiment at the end of the day and look at them again at the beginning of the next day.
- Make sure pennies are all pre-1983, as they have more copper than more recent pennies and will react faster.

You may want to instruct students to write their answers and draw pictures on separate pieces of paper so they will have more space.

Ongoing Assessment

- Describe what the pennies look like before the experiment. Describe what the paperclips look like before the experiment.
- What purpose does each of the ingredients serve? What do you think the salt is for? What do you think the vinegar is for?
- What do you think is going to happen?
- Describe what the pennies and paperclips look like during the experiment.
- Describe what the pennies and paperclips look like at the end of the experiment.

Safety and Disposal

- The vinegar and salt mixture can go down the sink.
- Rinse pennies with water and reuse.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Allow students time to carefully inspect their pennies and paperclips after the reaction has finished.

What happened to the paperclip?
It became coated with copper and appears copper.

Have the students hypothesize how the nail or the paperclip became copper colored.
Students may have different theories about how this happens.

How could this process be used by industry?
Plating metals, jewelry, coating a reactive metal with one that is less reactive, etc.

Why would we want to cover one kind of metal with another?
Sometimes it is too expensive to make an entire object out of an expensive metal. In those cases, the expensive metal can be plated onto a cheaper metal. Jewelry and expensive metal objects are often made of inexpensive metals with a thin layer of expensive metal on the outside. We call this "plating." Objects can be silver-plated, gold-plated, copper-plated, etc. Even pennies are plated objects! The government makes them by plating copper over zinc.

EXPLANATION

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

In this activity, students make a mixture of salt, vinegar, pennies, and paperclips. The pennies become shiny, and the paper clips become copper colored.

BACKGROUND FOR ALL GRADES

Properties of Metals

Metals are a group of chemicals with similar physical properties. Metals are shiny and (except for mercury) solid at room temperature. They are **ductile**, which means they can be bent, stretched, and molded into different shapes. Aluminum is commonly flattened for use as a foil; tin and steel are folded and stretched to make food cans. Metals are also good **conductors,** which means they transfer heat and electricity well**.** Copper metal is a particularly good conductor. That is why copper is used in electrical wiring, and why it is sometimes used to coat the bottoms of pots and pans.

Trading Places

In this reaction, copper atoms from the pennies replace iron atoms in the paperclips. First, the copper atoms **dissolve** in the vinegar salt solution. Then they travel through the solution to the paperclip. The iron atoms in the paperclip trade places with the copper in the solution. The copper becomes solid on the paperclip, and the iron dissolves into the vinegar and salt solution.

BACKGROUND FOR GRADES 6–8

Properties of Ions

If an atom loses or gains **electrons**, it becomes electrically charged. An electrically charged atom or group of atoms is called an **ion.**

Copper atoms are not able to dissolve in water, but copper ions are able to dissolve in water. In this activity the copper atoms on the pennies lose electrons to become ions. The acid and salt work together to help **dissolve** the copper ions into solution.

For more detail on how things dissolve in solution, read the Explanation section of the activity **Salting Out**.

Copper Plating

The copper ions travel in solution, and, if those ions reach the paperclip, they trade places with an iron atom. That iron atom loses electrons to become an ion in solution; the copper ion gains those electrons and becomes a copper atom on the paperclip. As this continues, the copper plate on the paperclips grows one atom at a time until the entire paperclip is coated. Once the paperclip is completely coated with copper, no more iron will react, because the outer layer of copper atoms protects it.

The iron in the paperclip is more reactive than the copper from the pennies. For this reason, the iron allows the copper to take its electrons, causing the iron to dissolve in solution and the copper to become solid on the paperclip. This process of coating the paperclip with copper is called **plating**.

If the jars sit for 1 to 5 days, grayish clumps may be visible in the solution. This is the iron that came off the paperclip.

Batteries
The transfer of electrons between metals also happens in a **battery**. In a battery, two different metals are combined with acid and separated from each other. The exchange of electrons is not allowed to happen directly between the metals. Instead, the electrons are forced to travel through a wire. A traveling stream of electrons is called **current**. This current of electrons is what we call **electricity**.

EXTENSIONS

Extension A: Inquiry Opportunity—Substitute Ingredients
Have students design their own experiments. Let them hypothesize what will happen when they substitute different metal objects for the pennies or the paperclips. Students can also take out or substitute one ingredient, like salt or vinegar, to see the effect of each ingredient on the experiment. They will gradually build a greater knowledge base by methodically recording their experiments.

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

Extension B: Electroplating (Grades 5–8)
Students will copper plate a metal object using a battery to transfer electrons.

Extra Supplies
For each group:
- ❑ steel wool
- ❑ two wire leads
- ❑ small jar
- ❑ salt
- ❑ ½ teaspoon measure
- ❑ battery (a 6-volt lantern battery works well)
- ❑ metal object to be plated
- ❑ copper object (coiled wire, pre-1983 penny, or strip)
- ❑ water

Extra Instructions

- Use steel wool or a paste of salt and water to gently polish or scour the surface of the metal object to be plated. This removes the surface layer of metal that has reacted with oxygen in the air, giving the copper a better place to stick.
- Connect lead #1 (an insulated wire with alligator clips at each end) to the negative terminal of a battery. Attach the other end of lead #1 to a metal object that you wish to plate, e.g., a key or a nickel.
- Connect lead #2 to the positive terminal of your battery. Attach the other end of lead #2 to a clean, bare coil of copper wire, a clean penny, or a clean strip of copper.
- Fill a small jar with water. Add ½ tsp of salt and stir the solution.
- Place the metal object to be plated and the copper object attached to lead #2 in the water. Do not let the two metal objects touch.
- Observe the solutions while the electroplating is taking place. The metal object attached to the negative terminal of the battery should become plated with metal from the object (copper) at the positive terminal of the battery. You should be able to see other evidence of chemical reactions, such as formation of tiny gas bubbles.
- Carefully rinse the solutions down the drain with ample water

Explanation

In the regular activity, copper spontaneously coats the iron paperclips because the iron is more reactive than the copper. When people want to plate copper on metals that are less reactive, or they want to plate copper on more quickly, they use batteries. The battery will remove electrons from the copper, creating positive copper ions that go into solution. The copper ions will be attracted to the electron-rich metal at the negative end of the circuit, and so will plate onto the metal object.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS

Worth Your Weight in Gold

Look in the newspaper or online for current market prices of gold, copper, and silver. Have students weigh silverware or coins and use multiplication to determine the value of the object if it were made exclusively of gold, copper, or silver.

LANGUAGE ARTS

Spelling List: Metals

Add some interesting metal names to your spelling list (e.g., lead, zinc, iron, magnesium, chromium, mercury).

SOCIAL STUDIES

Coin Collecting

Each coin is marked to show various facts including: where it was minted, the year it was made, the denomination of the coin. Also, in different years, pennies have different compositions. For instance, during World War II, the pennies were made of steel since copper was in short supply. After 1983, pennies were made from zinc with a copper plate because, again, copper became more expensive.

Start a coin collection with your class. Try to collect a penny from each year and from each minting location. Notice changes in the way pennies look from year to year.

RESOURCES

Web–http://www.jmckinley.com/us/metal-reactions.htm
Detailed discussion of silver jewelry and its reactions.

Web–http://electronics.howstuffworks.com/battery.htm
A detailed description of how batteries work. Good diagrams.

Web–http://www.energizer.com/learning/science/
Directions on making electrical circuits and batteries.

Web–http://www.unr.edu/sb204/geology/mas.html
This is a simplified table showing the comparative reactivity of different metals. Notice that iron is higher on the list than copper, so it is more reactive and allows copper to take its place on the paperclip.

Mathis, Sharon Bell, *The Hundred Penny Box*
Reading Level: 4th grade to 8th grade
Michael's great-great-aunt Dew has a box with a penny for every year of her life. She spends time with Michael telling stories about each of the hundred years of her life. Winner of a Newberry Honor.

VOCABULARY

atom: a very, very small particle that makes up all matter

battery: a combination of metals and other chemicals that react together to produce current, i.e., moving electrons

conductor: a material that transfers heat or electricity easily

current: a flow of electrons

dissolve: when the molecules of a substance separate and become completely surrounded by the molecules of another substance

ductile: can be stretched or bent without breaking

electricity: created by a continuous flow of electrons through a wire

electron: a tiny, negatively charged particle found in atoms and molecules

ion: an electrically charged atom or group of atoms

metal: any material that is shiny, can be molded, stretched or shaped, and transfers heat or electricity; can be an element or mixture of elements

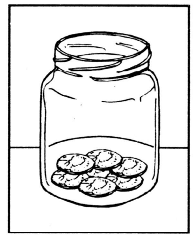
plating: covering the surface of one metal with a layer of another metal

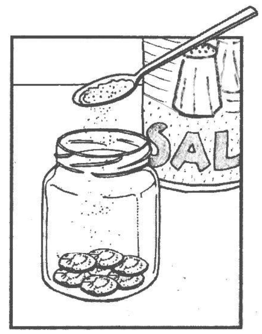
Penny for Your Thoughts

SCIENTIFIC PROCEDURE

1. Label a jar with your name(s).

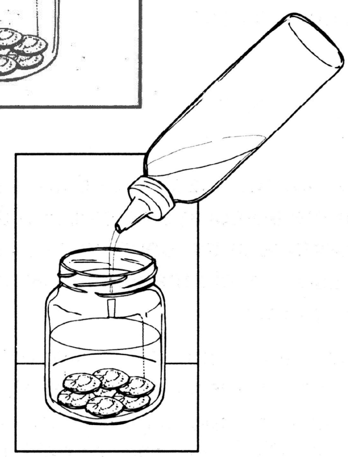
2. Put fifteen pennies in the jar.
    - What do the pennies look like?





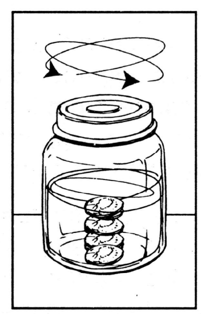
3. Add 2 spoonfuls of salt into the jar.

4. Fill the jar halfway with vinegar.
    - What does the salt and vinegar mixture look like?



5. Close the jar. Make sure the lid is tight.

6. Swirl the jar in circles until the contents have spun around 15 times.



7. Open the jar and add a paperclip.
    - What does the paperclip look like?

8. Close the jar. Make sure the lid is tight.

9. Look at the jar after 15–30 minutes

- What does the paperclip look like?
- What do the pennies look like?
- What does the solution around them look like?

10. Check back on your jar a day later.

- What does the paperclip look like?
- What do the pennies look like?
- What does the solution around them look like?

11. Clean up your area.

- Follow your teacher's instructions.

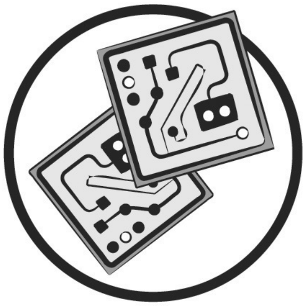
This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Penny for Your Thoughts

Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
small jars with lids (baby food jars work well)	1 per group		
vinegar	½ cup per group		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
salt	2 spoonfuls per group		
steel paperclips (or other small iron-containing objects)	3–4 per group		
pennies (must be pre-1983)	15 per group		
spoon	1 per group		
plastic cups, any size	1 per group		
Extension A			
needs will vary depending on experiment design			
Extension B			
steel wool	small amount		
wire leads	2 per group		
small jar	1 per group		
salt	½ spoon per group		
½ teaspoon measure	1 per group		
battery (a 6-volt lantern battery works well)	1 per group		
metal object to be plated	1 per group		
copper object (coiled wire, pre-1983 penny, or strip)	1 per group		
water			
Teacher Demonstration			
Copper Corrosion			
glass cup	1 for demonstration		
overhead projector	1 for demonstration		
copper coated steel BBs	about 50		
bleach	¼ cup (enough to cover BBs)		
disposable gloves	1 pair		



Sticky Situation

Learning Objectives: *Students learn that some mixtures can be separated using chemical properties.*

GRADE LEVEL

3–8

SCIENCE TOPICS

Atoms and Molecules
Chemical Reactions
Industrial Chemistry

PROCESS SKILLS

Describing and Defining
Measuring

GROUP SIZE

2–3

SNEAK PEAK inside …

ACTIVITY

Students make and test glue, which they make from mixing milk and vinegar.

STUDENT SUPPLIES

see next page for more supplies

non-fat powdered milk
vinegar
sturdy paper towels or coffee filters
baking soda, etc….

ADVANCE PREPARATION

see next page for more details

Make milk from milk powder
Fill bottles with vinegar, etc….

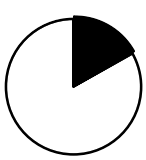
OPTIONAL EXTRAS

DEMONSTRATION
Glue Show and Tell (p. F - 40)

EXTENSIONS
Glue Inventions (p. F - 44)

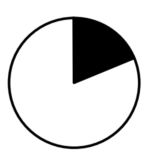
TIME REQUIRED

Advance Preparation



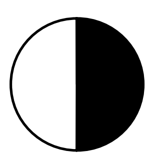
10 minutes

Set Up



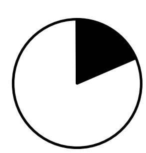
10 minutes

Activity



30 minutes

Clean Up



10 minutes

SUPPLIES

Item	Amount Needed
non-fat dry milk powder	1 cup per class
water	3–6 cups per class
vinegar	¼ cup per group
baking soda	1 tsp per group
pop-top squeeze bottles (e.g., water or sports drink)	2 per group
plastic cups	3 per group
wooden craft sticks (e.g., popsicle sticks)	1–2 per group
plastic spoons	1–2 per group
strainers	several for class to share
scraps of paper	5–8 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Milk Solution:

- This recipe makes a total of 4 cups of milk solution, or enough for 16 groups. Adjust the recipe if you have more groups than this.
- Add 1 cup of non-fat dry milk powder to 3 cups of water. Mix well.
- Fill pop-top squeeze bottles with about ¼ cup in each bottle.
- Label these bottles “milk.”

Vinegar

- Fill pop-top squeeze bottles with about ¼ cup of vinegar.
- Label these bottles “vinegar.”

Baking Soda

- Fill plastic cups with about 1 teaspoon of baking soda.
- Label these cups “baking soda.”

SETUP

For each group
- milk in pop-top squeeze bottle
- vinegar in pop-top squeeze bottle
- baking soda in plastic cup
- 2 empty plastic cups
- 1–2 plastic spoons
- 1–2 wooden craft sticks
- sturdy paper towel or coffee filter
- 5–10 scraps of paper

At a central location (or with the teacher)
- several strainers for class to share
- towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

Students will use milk and vinegar to create a glue that can stick paper together.

What does glue look like? What does it feel like? Or smell like?
Glue is sticky. Some glue is liquid when you use it, but it dries hard. Some dries like a thin skin. Some glues are stronger than others. Some glues have a strong smell.

Are all glues the same? How are they the same? How are they different?
Glues are not all the same. Examples include: white liquid school glue, clear or bluish school glue, yellowish liquid mucilage glue, solid glue sticks, strong-smelling industrial-strength glue, epoxy that must be mixed, fast-drying superglue, spray glue, hot-glue-gun gel sticks, yellow wood glue, slow-drying book-bonding glue, denture glue, etc.

Why are there so many different kinds of glue?
Each glue is designed for a different purpose. Each surface (paper, wood, cloth, glass, plastic, fabric) needs a different kind of glue to stick together. Some glues are permanent (super glue) but some are temporary (Post-it Notes, cereal boxes). Some glues need to be waterproof (denture glue).

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Glue Show and Tell

Bring a variety of different kinds of glue to show students. Discuss the properties of each glue and how it is specially designed for its purpose. You can also work with students to create categories for the different glues. Some examples are listed to help you get started.

Non-Toxic	Waterproof	Weak vs. Strong
glue stick	super glue	Post-it Notes
white glue	fabric glue	stickers
clear glue	wood glue	labels
Post-it Notes		
stickers		super glue
stamps		epoxy
rubber cement		
denture glue		

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page F - 47, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

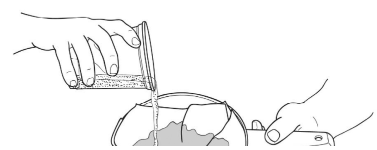
NOTES

Sticky Situation

This handout is on p. F - 47.

SCIENTIFIC PROCEDURE

1. Add 3 spoonfuls of milk into the plastic cup.
   - Describe the milk. What does it look like? What does it smell like?
2. Add 3 spoonfuls of vinegar into the cup with the milk.
3. Mix the milk and vinegar together with a wooden stick.
   - What is happening to the milk?
   - What does it look like? What does it smell like?



4. Place a paper towel or coffee filter inside a

Running Suggestions

- When students mix the milk and vinegar together, they will notice a strong "sour milk" smell. This reaction is similar to the reaction that occurs when bacteria spoils milk, so it makes a similar smell.
- Test the experiment yourself with a paper towel or coffee filter. If your filter does not work well (it filters too slowly or it breaks), try other methods. Coffee filters are stronger, but also tend to filter slowly. Paper towels will filter faster but are weaker.
- To minimize messes, encourage students to do all their experiments on a cafeteria tray.

You may want to have students answer questions and draw pictures on separate pieces of paper so they will have more space.

Ongoing Assessment

- Encourage students to make careful observations of what happens to the milk as vinegar is added.
- Where do the solid parts come from? (*The milk is changing from liquid to solid*.)
- Is all of the milk changing to a solid? (*No, some parts stay liquid*.)

Safety and Disposal

- All materials may be thrown in the trash when finished.
- Refrigerate unused milk solution and use within two weeks.

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

The sticky substance students made in this activity is able to glue paper together. Although it may not seem sticky at first, once it dries, the paper should stay together very well.

What happened when vinegar was added to the milk?
It clumped, or became solid (curdled). It smelled bad, like spoiled milk. A chemical change occurred. The liquid milk separated into solid white curds and clear liquid whey.

What happened when baking soda was added to the curds?
Bubbles appeared. The baking soda (a base) reacted with the vinegar (an acid) to produce a gas (carbon dioxide).

Have you heard the rhyme "Little Miss Muffet sat on her tuffet eating her curds and whey…"? Have you ever eaten curds or whey?
Most cheeses are made from the curds of milk. Cottage cheese is the most obvious example. Spoiled milk also forms solid curds. Whey is the liquid part of milk. Low-fat milk and non-fat milk have more whey than whole milk.

What would happen if you change the formula (or recipe) for this glue? For example, what if you use less vinegar in the formula?
Let students predict what they think will happen in different scenarios. The glue might be more sticky, less sticky, more liquid or more solid. The glue could dry really fast or dry very slowly.

Record students' suggestions for use in Extension A. This extension allows students to experiment in creating different glue recipes.

EXPLANATION

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

In this activity, students discovered that milk and vinegar react to create a sticky solid. This solid can be used to make paper stick together.

What's in Milk

Milk is a mixture of water, milk sugar (lactose), fats, **protein**, and small amounts of other nutrients, such as vitamins and minerals. Milk is a special kind of mixture known as an **emulsion** since it has several components that do not **dissolve** in one another. The fats and proteins are in tiny droplets that are suspended in the water of the milk. Other emulsions students may be familiar with are mayonnaise and some salad dressings. Students can look on the ingredient labels for items listed with the description "added as an emulsifier" or "added as a stabiliser." An **emulsifier** is anything added to make two liquids that won't dissolve (like oil and vinegar) to stay mixed together.

Separating Milk Protein

The major protein in cow's milk is called **casein**. Casein, like other proteins, has a three-dimensional shape that determines its behavior, its characteristics, and its properties. If the shape of the protein changes, then the properties of the protein will change. When the shape of a protein is changed, it is called **denaturing** the protein. Denatured proteins can look and act differently.

One way to denature a protein is through heat. The protein in egg whites (called **albumin**) turns from a clear liquid to a white solid when it is heated. Another way to denature a protein is by adding an **acid**. When students add vinegar (an acid) to the milk, the casein in the milk changes its shape and becomes denatured. The denatured milk protein turns from a liquid to a solid. This solid part of milk is also called **curds**; the liquid part of milk is called **whey**.

Fresh milk is not acid or a **base**, it is **neutral**. As milk ages, bacteria can grow in the milk, and these bacteria start to produce acid. This is why old milk spoils and has solid parts in it.

Students filter out the solid casein to use as glue. The casein still has traces of vinegar on it, so students add baking soda (a base) to neutralize their glue. Vinegar and baking soda react to produce new chemicals, including water and carbon dioxide gas. The bubbles students see is the carbon dioxide gas, the same as we exhale from our lungs and that makes up the bubbles in soft drinks.

For more information about acids, bases, and the pH scale, see the activity **Of Cabbages and Kings**.

Polymer Chemistry
Proteins are long molecules made of smaller repeating units and are a kind of **polymer**. Other naturally occuring polymers are DNA and starch. In this activity, students used this polymer as a glue. Regular white glue is also a polymer called polyvinyl alcohol. Industrial chemists often create new polymers in the development of glues, plastics and fabrics.

EXTENSIONS

Extension A: Glue Inventions
Students experiment with different ingredients and different ratios of ingredients to invent new glues. They test their new glue solutions and compare them to store glue.

Extra Supplies

- different kinds of milk (whole milk, low-fat milk, non-fat milk, soy milk)
- different kinds of acid solutions (vinegar, lemon juice, soda)
- measuring spoons
- various scraps of different kinds of paper (construction paper, tissue paper, cardboard)

Extra Instructions

- Students can follow the same procedure as the main activity, just substitute different solutions for the milk and vinegar.
- Students can change the recipe in the main activity and measure different amounts of milk and vinegar.
- Make certain that students write down their recipes.
- Students should test their glues on paper and compare the usefulness of their glue to traditional glues.

Explanation

What students are doing in this extension is similar to what chemists do in any industry when they are trying to create something new. Often, chemists start with a recipe that works for one purpose and adjust that recipe to adapt it for a new purpose.

CROSS-CURRICULAR CONNECTIONS

TECHNOLOGY

Pasteurization
What is pasteurization? Who discovered it? How has it impacted society? Before refrigeration, milk was a common carrier of tuberculosis bacteria. Have students read about the history of tuberculosis or interview senior citizens about tuberculosis in their generation or their parents' generation.

ART

Collage
Have the students use their glue to make collages with different colors and textures of paper. They can also make collages using pictures from magazines.

RESOURCES

Web – http://solutions.3m.com/en_US/
The Minnesota Mining and Manufacturing (3M) Company started out making sandpaper and now makes every type of tape, label, glue, and sticker imaginable. If you are having trouble thinking of different kinds of adhesives, take a look at their product line.

Web – http://www.3m.com/intl/uk/3mstreetwiseuk/teachers_landing_page.htm
The 3M Company has a curriculum about safety that is free for teachers. Use this link to request teaching materials.

Cleeland, Holly, *Glue & Go Costumes for Kids: Super-Duper Designs with Everyday Materials*
Using just a glue gun and easy-to-find materials (fabric, cardboard boxes, plastic cups, foam core), you can make unique costumes. Book includes full-color photographs.

Wolf, Allan, *Haiku Stickies: 100 Haiku to Write & Leave Behind*
A pad of partial haiku poems is included with this book. Each poem has blank spaces for children to fill in; earlier in the pad, they'll need to add only a word or two, while the later haiku will have kids writing nearly from scratch.

VOCABULARY

acid: a compound with an excess of available hydrogen ions; often sour in taste

albumin: protein found in egg whites

base: a chemical compound that takes up hydrogen ions; often bitter in taste

casein: protein found in cow milk

curds: the solid part of milk

denature: to cause a protein to change its shape; when a protein changes its shape and therefore loses its properties

dissolve: when the molecules of one substance separate and become completely surrounded by the molecules of another substance

emulsifier: something added to two liquids that normally won't dissolve to keep them uniformly mixed

emulsion: a suspension of tiny droplets of one liquid in a second liquid; the two liquids do not normally dissolve in one another

neutral: a chemical that is neither acid nor base; typically has a pH of 7

polymer: a large molecule made up of many repeated molecules

whey: the liquid part of milk

Sticky Situation

SCIENTIFIC PROCEDURE

1. Add 3 spoonfuls of milk into the plastic cup.
   - Describe the milk. What does it look like? What does it smell like?

2. Add 3 spoonfuls of vinegar into the cup with the milk.

3. Mix the milk and vinegar together with a wooden stick.
   - What is happening to the milk?
   - What does it look like? What does it smell like?

4. Place a paper towel or coffee filter inside a strainer. Put an empty plastic cup under the strainer.

5. Carefully pour your mixture into the strainer. Wait for the liquid to filter through the strainer and into the cup.

6. Gently lift the paper towel or coffee filter out of the strainer.
   - Describe the solid you collected. What does it look like? How does it feel?

7. Sprinkle a pinch of baking soda onto the solid.
   - What happens?

8. Use the glue you made to stick paper together. Leave the paper alone until the glue is dry.

9. Clean up your area.
   - Follow your teacher's directions.

This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Sticky Situation

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
non-fat dry milk powder	1 cup per class		
water	3–6 cups per class		
vinegar	¼ cup per group		
baking soda	1 tsp per group		
pop-top squeeze bottles (e.g., water or sports drink)	2 per group		
plastic cups	3 per group		
wooden craft sticks (e.g., popsicle sticks)	1–2 per group		
plastic spoons	1–2 per group		
strainers	several for class to share		
scraps of paper	5–8 per group		
Extension A			
different kinds of milk (whole milk, low-fat milk, non-fat milk, soy milk)	¼ cup each milk per group		
different kinds of acid solutions (vinegar, lemon juice, soda)	¼ cup each acid per group		
Teacher Demonstration			
Glue Show and Tell			
variety of different glues	1 or more each kind		

Escoge tu Lodo

PROCEDIMIENTO A

1. Marca un vaso de papel con la palabra "Flubber."
   Marca un vaso de papel con la palabra "Glarch."

2. Agrega 3 cucharadas de pegamento blanco en cada vaso.
   - *¿Cómo es el pegamento blanco?*

3. Al vaso de "Flubber," agrega 1 cucharada de la solución de Bórax.
   Revuelve con una paleta de madera.
   - *¿Qué le sucede a la mezcla?*

4. Saca el Flubber del vaso.
   - *¿Cómo se siente?*
   - *¿Rebota?*
   - *¿Se estira?*

5. Al vaso de "Glarch," agrega 1 cucharada de la solución de Staflo.
   Revuelve con una paleta de madera.
   - *¿Qué le sucede a la mezcla?*

6. Saca el "Glarch" del vaso.
   - *¿Cómo se siente?*
   - *¿Rebota?*
   - *¿Se estira?*

7. Limpia tu área de trabajo.
   - *Sigue las instrucciones de tu maestro(a)*

Escoge tu Lodo

PROCEDIMIENTO B

1. Identifica cinco vasos de papel con los números del #1 al #5.
2. Agrega pegamento blanco a cada vaso de acuerdo a la tabla.
3. Al vaso #1, agrega 2 cucharadas de la solución de Staflo Revuelve con una paleta de madera.
   - *¿Qué le sucede a la mezcla?*
   - *Escribe tus respuestas en la tabla de datos.*

4. Saca el "lodo" del vaso.
   - *¿Cómo se siente? ¿Rebota? ¿Se estira?*
   - *Escribe tus observaciones en la tabla de datos.*
5. Repite los pasos 3 y 4 con el resto de los vasos.
   - *¿Qué propiedades del "lodo" cambian a medida que cambia la cantidad de pegamento?*
6. Limpia tu área de trabajo.
   - *Sigue las instrucciones de tu maestro(a)*

vaso	1	2	3	4	5
pegamento blanco	4 cucharadas	5 cucharadas	6 cucharadas	7 cucharadas	8 cucharadas
Staflo	2 cucharadas	2 cucharadas	2 cucharadas	2 cucharadas	2 cucharadas
notas					

Escoge tu Lodo

PROCEDIMIENTO C

Sustitución de Pegamento en Flubber

1. Identifica dos vasos de papel con las palabras: "Flubber" y "Flubber Transparente."

2. Agrega pegamento blanco o pegamento transparente de acuerdo a la tabla.

	pegamento	Bórax	notas
Flubber	3 cucharadas de pegamento blanco	1 cucharada	
Flubber Transparente	3 cucharadas de pegamento transparente	1 cucharada	

3. A los vasos de "Flubber" y "Flubber Transparente" agrega 1 cucharada de solución de Bórax.

4. Revuelve con una paleta de madera.
   - ¿Qué le sucede a cada una de las mezclas?
   - Escribe tu respuesta en la tabla.

5. Saca los dos tipos de Flubber de los vasos.
   - ¿Cómo se sienten? ¿Rebotan? ¿Se estiran?
   - Escribe tus respuestas en la tabla.

6. Compara las propiedades del "Flubber" y "Flubber transparente".
   - ¿En qué se parecen?

   - ¿En qué son diferentes?

7. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Escoge tu Lodo

PROCEDIMIENTO C

Sustitución de pegamento en Glarch

1. Identifica dos vasos de papel con las palabras: “Glarch,” y “Glarch Transparente.”

2. Agrega pegamento blanco o transparente de acuerdo a la tabla.

	pegamento	Staflo	notas
Glarch	3 cucharadas de pegamento blanco	1 cucharada	
Glarch Transparente	3 cucharadas de pegamento transparente	1 cucharada	

3. A los vasos de “Glarch” y “Glarch Transparente” agrega 1 cucharada de solución de Staflo

4. Revuelve con una paleta de madera.
   - ¿Qué sucede con cada una de las mezclas?
   - Escribe tu respuesta en la tabla.

5. Saca los dos tipos de Glarch de los vasos.
   - ¿Cómo se sienten ¿Rebotan? ¿Se estiran?
   - Escribe tus respuestas en la tabla.

6. Compara las propiedades del “Glarch” y del “Glarch transparente”.
   - ¿En qué se parecen?
   - ¿En qué son diferentes?

7. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

Escoge tu Lodo

PROCEDIMIENTO C

Sustitución de Staflo en Glarch

1. Identifica cuatro vasos de papel del #1 al #4.

2. Agrega 3 cucharadas de pegamento blanco a cada vaso.

3. Al vaso #1, agrega una cucharada de la solución de Staflo

- Revuelve con una paleta de madera.
- ¿Qué le sucede a la mezcla?
- Escribe tu respuesta en la tabla de datos.

4. Saca el "lodo" del vaso.

- ¿Cómo se siente? ¿Rebota? ¿Se estira?
- Escribe tus observaciones en la tabla.

5. Repite los pasos 3 y 4 con los otros vasos.
Sustituye una solución diferente de Staflo en cada vaso de acuerdo a la tabla.

6. Compara las diferentes versiones de Glarch.

- ¿Puedes utilizar una "Solución Secreta" para hacer Glarch?
- **Explica:** ¿Cómo lo sabes?

- ¿Qué hace que el pegamento se convierta al "lodo"(el almidón o el Bórax)?
- **Explica:** ¿Cómo lo sabes?

- ¿Qué propiedad crea el almidón en el "lodo"?
- **Explica:** ¿Cómo lo sabes?

- **Escoge tu "lodo":** ¿Qué receta de Glarch te gusto más?
- **Explica:** ¿Por qué es esta receta la mejor opción?

7. Limpia tu área de trabajo.

- Sigue las instrucciones de tu maestro(a).

Escoge tu Lodo

PROCEDIMIENTO C – TABLA DE DATOS

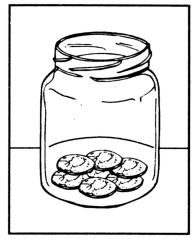
Sustitución de Staflo en Glarch

	1	2	3	4
	Glarch	Solución Secreta de Glarch	Glarch, sin Bórax	Glarch, Sin almidón (Flubber)
pegamento	3 cucharadas de pegamento blanco	3 cucharadas de pegamento blanco	3 cucharadas de pegamento blanco	3 cucharadas de pegamento blanco
Staflo	1 cucharada			
Solución Secreta		1 cucharada		
almidón			1 cucharada	
Bórax				1 cucharada
notas				

Una chapa barata

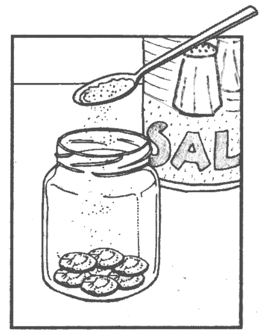
PROCEDIMIENTO CIENTÍFICO

1. Marca un frasco con
tu (sus) nombre(s).



2. Coloca 15 centavos en el frasco.

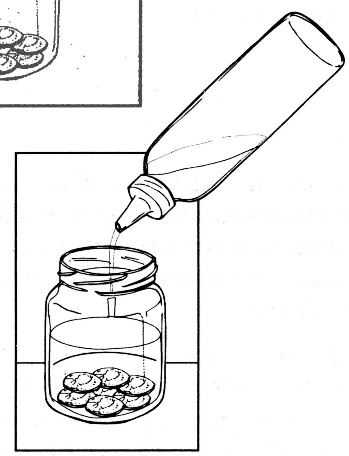
- ¿Cómo se ven los centavos?



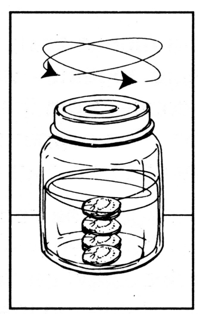
3. Agrega 2 cucharadas de sal al frasco.

4. Llena el frasco hasta la mitad con vinagre.

- ¿Cómo se ve la mezcla de sal y vinagre?



5. Cierra el frasco.
Asegúrate de que la tapa esté bien apretada.



6. Revuelve el frasco hasta
que el contenido haya dado 15 vueltas.

7. Abre el frasco y agrega un clip.

- ¿Cómo se ve el clip?

8. Cierra el frasco.
Asegúrate de que la tapa esté bien apretada.

9. Después de 15-30 minutos mira el frasco.

- *¿Cómo se ve el clip?*

- *¿Cómo se ven los centavos?*

- *¿Cómo se ve la solución que está en el frasco?*

10. Revisa el frasco al día siguiente.

- *¿Cómo se ve el clip?*

- *¿Cómo se ven los centavos?*

- *¿ Cómo se ve la solución que está en el frasco?*

11. Limpia tu (su) área de trabajo

- Sigue las instrucciones de tu maestro(a).

Situación Pegajosa

PROCEDIMIENTO CIENTÍFICO

1. Agrega 3 cucharadas de leche en el vaso de plástico.
    - Describe la leche. ¿Cómo se ve? ¿A qué huele?

2. Agrega 3 cucharadas de vinagre en el vaso de leche.

3. Mezcla la leche y el vinagre con una paleta de madera.
    - ¿Qué le sucede a la leche?
    - ¿Cómo se ve? ¿A qué huele?

4. Coloca una toalla de papel o un filtro de café dentro de un colador. Coloca un vaso de plástico vacío debajo del colador.

5. Cuidadosamente vierte tu mezcla en el colador. Espera a que el líquido se filtre a través del colador y caiga en el vaso.

6. Con cuidado levanta la toalla de papel o filtro de café del colador.
    - Describe la materia sólida que recolectaste. ¿Cómo se ve? ¿Cómo se siente?

7. Polvorea la materia sólida con un poquito de bicarbonato de sodio.
    - ¿Qué sucede?

8. Utiliza el pegamento que hiciste para pegar papel. No toques el papel hasta que el pegamento esté seco.

9. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

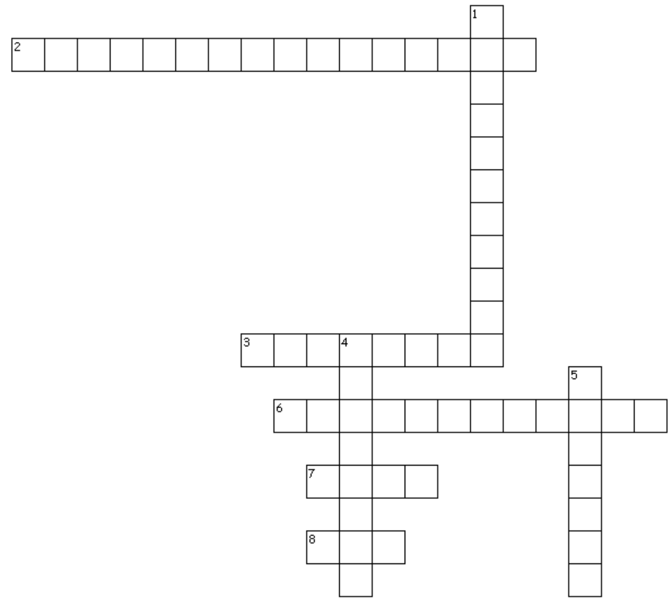
Concepts

Objects that people use are made of chemicals. Many industries rely on chemistry to produce items.

Words to know

- **atom** — a very, very small particle that makes up all matter.
- **electron** — a tiny, negatively charged particle found in atoms.
- **chemical bond** — a connection that holds two or more atoms or molecules together.
- **chemical reaction** — when two or more substances combine to create a new substance; often characterized by fizzing, color change, change in temperature or creation of light.
- **ion** — an electrically charged atom or molecule.
- **molecule** — a group of at least two atoms held together in a definite arrangement.
- **polymer** — a large molecule that is made of many smaller molecules linked together.
- **polystyrene** — long chains of styrene molecules; this plastic is mainly used for cups and food containers.

Use the clues and the Words to Know to complete the crossword puzzle.



Across

2. In a _____ _____ interaction of atoms or compounds leads to the formation of new atoms or compounds.
3. A small particle made of two or more atoms is a _____.
6. A _____ _____ is a connection that holds two or more atoms or molecules together.
7. A very, very small particle that is the building-block that makes up all matter is called an _____.
8. An _____ is a tiny, negatively charged particle found in atoms.

Down

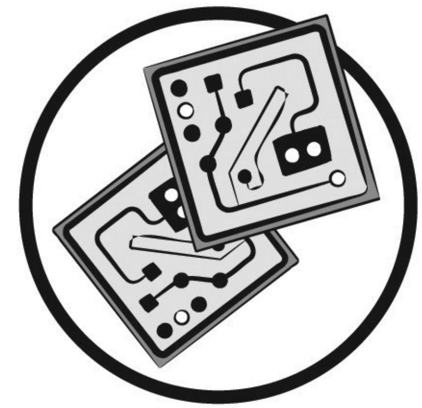
1. _____ is composed of long chains of styrene molecules.
4. The tiny, negatively charged particle found in atoms is the _____.
5. A _____ is a large molecule made from many similar small molecules.

OMSI

OREGON MUSEUM OF SCIENCE AND INDUSTRY

CheM LaB

Take-Home Activities

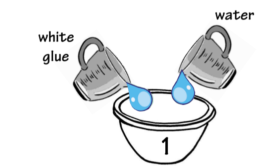


Industrial Chemistry

Flubber

Make a polymer!

Materials:



Container 1 (3-cup capacity)
1/2 cup warm water
2/3 cup white glue
Food coloring (a few drops)

Container 2
1/3 cup warm water
1 teaspoon borax

To do and notice:

1. Mix the ingredients in each container thoroughly. What do they look like? How are they different?
2. Pour Container 2 into Container 1. Gently lift and turn the mixture until only about a tablespoon of liquid is left. **What do you observe? What does it feel like?** The Flubber will be sticky for a moment or two. Let the excess liquid drop off, and the Flubber will be ready.

What happens to the Flubber when . . .
it is stretched?
it is rolled into a ball and bounced?
it is stretch over the opening of a jar?
an object (golf ball, etc.) is rolled on it?

A closer look:

Flubber is a polymer made by a chemical reaction. Polymers are very long chains of repeating units. When the two solutions are combined, polyvinyl acetate chains (a polymer from the glue) are linked together in a 3-dimensional arrangement by borate ions (from the borax) and other chemical bonds. This produces the thick, sticky polymer called "Flubber."

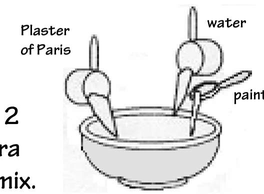
Chalk it Up

Make your own sidewalk chalk!

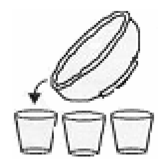
Materials:

2 tablespoons powdered tempera paint
1 cup Plaster of Paris
plastic tub (yogurt or margarine container)
old spoon or stick
water
small paper cups
gloves (optional)

To do and notice:



1. Mix 1 cup Plaster of Paris with 2 tablespoons powdered tempera paint in the bowl. Stir well to mix.
2. Add about ½ cup of water, a little at a time, stirring well after each addition. The mixture should be smooth like thick cake batter.
3. Pour the mixture into the paper cups.



4. Let the cups dry for 1 day
   CAUTION: When cleaning up, do not pour extra Plaster of Paris into the sink. Throw it away into the trash.
5. When the mixture is completely dry and hard, peel off the paper cups. You have made chalk!
   - **How does your chalk look and feel?**
   - **Can you use your chalk to write on the sidewalk?**
6. Try the procedure again with different colors of paint.

A closer look:

Plaster of Paris is made of calcium sulfate ($CaSO_4$). When you add water to the dry plaster, the water molecules bind the calcium sulfate molecules together, forming a hard mass. The paint provides the color for your chalk. This colored solid is scraped off as you write with it.

Calcium sulfate is also used in the manufacture of artificial marble, wall plaster, gypsum sheetrock, and concrete.

Shrinkers

Cook up some plastic!

Materials:

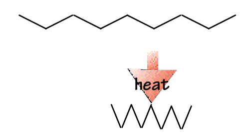
polystyrene (#6) plastic from cup or take-home box
scissors
permanent marker (optional)
non-stick pan
stove
plastic spatula or tongs
bowl of water

CAUTION: This project uses a hot stove. Adult supervision is required.

To do and notice:

1. Use the scissors to cut your plastic into squares about 2in by 2in.
2. Write your name on the plastic using a permanent marker.
3. Heat the non-stick pan on the stove until it is very hot. **CAUTION: This project uses a hot stove. Adult supervision is required.**
4. Put your plastic in the pan. After 10 seconds, turn over the plastic using a plastic spatula or tongs. Continue to heat and flip the plastic every 10 seconds until the plastic has finished shrinking.
5. Remove the plastic from the pan and put it in the bowl of water to cool. Take your plastic out of the water.
   - **Can you read your writing on the plastic?**

A closer look:



Polystyrene molecules are made of long zigzag-shaped chains of carbon atoms. During the manufacturing process the plastic is heated, stretched into shape, and cooled. This process freezes the molecules in a stretched-out position.

When you heated the piece of polystyrene, the molecules returned to their original zigzag shape. Thus, the plastic shrank.

Plastic cups are stretched in one direction when they are made, so they will shrink in only one direction. Plastic trays are stretched in two directions, so they will shrink in two directions.

Dye Detective

Learning Objectives: *Students learn chemicals can be separated when they have different chemical properties.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Physical Properties
Atoms and Molecules
Solutions and Mixtures
Techniques

PROCESS SKILLS

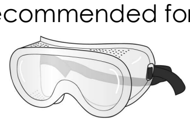
Classifying
Organizing Data
Inferring
Analyzing

GROUP SIZE

1–3

for procedure B:

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students use water and paper to separate the colors in black marker inks.

STUDENT SUPPLIES

see next page for more supplies

washable black markers
plastic cups
pencils, tape
filter paper (e.g., coffee filters), etc.…

ADVANCE PREPARATION

see next page for more details

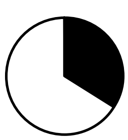
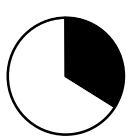
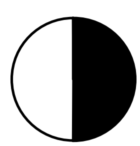
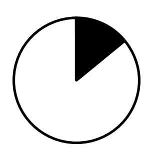
Cut strips of paper, if necessary
Label markers, etc.…

OPTIONAL EXTRAS

DEMONSTRATION
Modeling the Procedure (p. G - 7)

EXTENSIONS
Calculating the "Retention Factor" (p. G - 13)
Inquiry Opportunity—Different Liquids (p. G - 14)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
20 minutes	**20 minutes**	**30 minutes**	**5–10 minutes**

SUPPLIES

Activity Note:
This activity has two different procedures:

Procedure A: Recommended for younger grades, this activity uses only water and water-based markers.

Procedure B: Recommended for older grades, this activity uses water, alcohol, and water-based and waterproof markers.

Item	Amount Needed
Procedure A	
clear, plastic cups (8 oz. or 12 oz.)	1 per group
watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels	2–3 per group
water-based (washable) black markers, each from a different brand (e.g. Vis-à-vis™, Flair™, or Mr. Sketch™)	3–5 per group
pop-top squeeze bottles (e.g., water or sports drink)	1 per group
water	¼ cup per group
clue papers*	1–2 sheets per class
long, rigid object to lay across the top of cup (pencils, pens, wooden craft sticks, etc.)	1–2 per group
Procedure B	
clear, plastic cups (8 oz. or 12 oz.)	1 per group
watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels	2–3 per group
water-based (washable) black markers, each from a different brand (e.g. Vis-à-vis™, Flair™, or Mr. Sketch™)	3–5 per group
permanent (water proof) black markers, each from a different brand (e.g. Sharpie™)	3–5 per group
pop-top squeeze bottles (e.g., water or sports drink)	2 per group
water	¼ cup per group
alcohol, rubbing alcohol or isopropyl alcohol	¼ cup per group
long, rigid object to lay across the top of cup (pencils, pens, wooden craft sticks, etc.)	1–2 per group
tape	1 roll per group

* See Advance Preparation

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Chromatography Strips (for Procedures A and B)

- Strips of paper from watercolor paper, coffee filters, or fine-grained paper towels. Alternatively, use commercially available chromatography paper (Whatman is a good supplier).
- The size 2" x 3" seems to work well for 8 oz. cups. The strips should be long enough to reach down into the cup of water after being taped to a pencil, pen, or stick that is laid across the top of the cup (see Figure 1). They should also be wide enough for students to mark with the marker.
- Alternatively, cut the strips wider and curl them into a cylinder that stands by itself in the cup (See Figure 2).

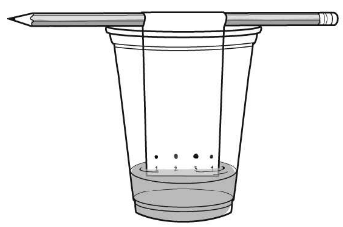


Figure 1. Older students can cut strips of filter paper to hang from the top.

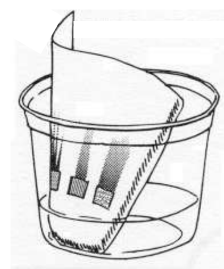


Figure 2. Younger students can use coffee filters that stand on their own in cups

- Remember, don't cut the strips longer than the cups they hang in. Strips should be ~ ½" shorter than the height of the cup. This allows the strips to hang down from the top so that their bottom edge is just touching the liquid in the cup.

Clue Paper (optional) (For procedures A and B):

- A fun way to introduce the activity is to give students a sample of a "mystery" marker.
- Prepare strips of paper as above, one or more for each group.
- On the paper, make a mark with a specific pen just as students will do in the activity.
- Label these strips **in pencil** "Clue Paper."
- During the activity, students can use the Clue Paper and compare the results to other markers they test. Then they can determine which marker was used on the Clue Paper.

Markers (for procedures A and B):

- Label each different brand marker with masking tape: #1, #2, #3, etc., or have students do this. Make sure all markers with the same brand get the same number.
- If you are using Clue Papers, make certain that one of the brands the students have available to them is the same as the one on the Clue Paper.
- Vis-à-vis brand is particularly colorful.
- **For older students,** use a mixture of water-based and permanent markers. Permanent markers only separate in alcohol solutions, while washable or water-based markers will separate in water solutions.

Water (for procedures A and B):

- Fill pop-top squeeze bottles with about 1 cup of water.
- Label these bottles "water."

Alcohol (for procedure B):

- You can use isopropyl alcohol that is at least 70% concentration to separate the dyes in permanent marker ink.
- Make sure you use the same concentration for all bottles used in this activity. The separation of markers is different for different concentrations of alcohol.
- Fill pop-top squeeze bottles with alcohol.
- Label these bottles "alcohol."

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

Notes and Hints

- During the activity, try covering the top of the cup to prevent the liquid evaporating off the surface of the paper. This is especially helpful for the rubbing alcohol. A plastic bag placed over the top, or a wider plastic cup inverted on top, work well. Alternatively, cut the top off of a 2-liter soda bottle and invert the bottle over the plastic cup to create a closed chamber.
- Younger students might prefer to use cone-shaped coffee filters, which can stand up on their own in plastic cups (see diagram). If doing this, tear the filter in half (one sheet thick instead of two) as it works better this way.

SETUP

Procedure A
(investigating only washable markers)
<u>For each group</u>
- ❑ 1 clear plastic cup or glass jar, 8–12 oz. size
- ❑ 2–3 cone-shaped #2 size coffee filters **OR** other filter paper strips, for example: 2" x 3" strips of watercolor paper or fine-grained paper towels
- ❑ 3–5 water-based (washable) black markers from different brands
- ❑ water in pop-top squeeze bottle
- ❑ 1 "Clue Paper" (optional)

Procedure B
(investigating washable and permanent markers)

<u>For each group</u>
- ❑ 1 clear plastic cup or glass jar, 8–12 oz. size
- ❑ 2–3 cone-shaped #2 size coffee filters **OR** other filter paper strips, for example: 2" x 3" strips of watercolor paper or fine-grained paper towels
- ❑ 3–5 water-based (washable) black markers from different brands
- ❑ 1–2 permanent black markers (different brands)
- ❑ alcohol in pop-top squeeze bottle
- ❑ water in pop-top squeeze bottle
- ❑ 1 "Clue Paper" (optional)

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students pass water or alcohol over black ink marks on paper to separate the colors out. Forensic scientists use this technique, **chromatography**, to analyze and identify mixtures of chemicals (e.g., ink, lipstick, or paint) left at crime scenes.

For K–2 students

Pretend you have only red, yellow, blue, black, and white paint. How would you make purple paint? How about green? How about brown?
Mix red and blue to make purple, mix yellow and blue to make green, mix many colors to get different shades of brown.

Student volunteers can choose and mix colors, if you have them.

After you have mixed the paints, can you get the colors apart again?
Let the students hypothesize ways to separate colors. How would they test their ideas?

In this activity, students will try to separate colors found in marking pens.

For all students

What kind of clues might you find at the scene of a crime?
Pieces of fabric, paint, fingerprints, hair, blood, DNA, dirt from shoes, ransom notes, dropped wallets, forged checks, etc.

If you found fingerprints from the scene of a crime, how would you match them to a suspect?
Every person's fingerprints have a unique pattern that identifies them.

If you found a piece of fabric at the scene of a crime, how would you find out whether the fabric came from the suspect's car?
Hint: Does the texture match? Does the color match? Forensic scientists match fabrics by finding matches between several characteristics of the fabric.

If you found a forged check, or a ransom note, or a letter written by the suspect, could you analyze the ink and match it to the suspect?
These items can be examined for fingerprints or subjected to handwriting analysis. However, forensic chemists can also chemically analyze the ink used in the papers by a technique called "chromatography." Chromatography can show the brand of marker used, which might be linked to a particular suspect.

Modeling the Procedure
You may want to model the procedure for students so they have the best success with the chromatography.

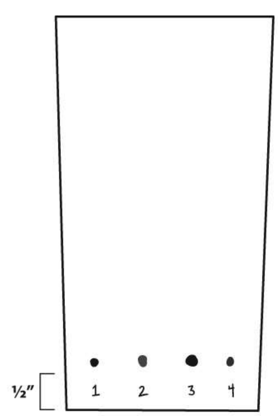
There are really only two mistakes that create bad results.

Mistake #1
Using anything other than a pencil to label the filter paper.

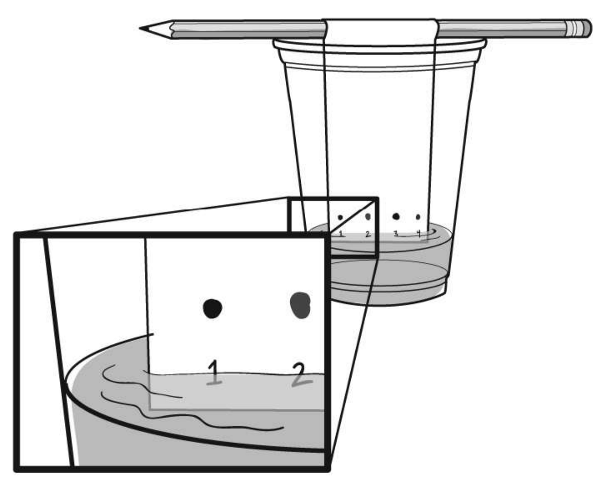
This activity is about separating the dyes in ink. If students use pen to label their papers, the ink in the label will separate and move up the paper. This means the labels will interfere with the chromatogram of the experiment. And they can't read their labels.

Mistake #2
Marking their dots too low on the paper.

The water moving up the paper carries the ink up the paper as well. If the ink dots are so low they reach the liquid, they will dissolve and diffuse out into the liquid. This means the inks will not run up the paper and separate as well.



MAKE SURE the dots are at least ½" from the bottom



Only the very end of the paper should touch the water. **DO NOT** let water touch your ink spots.

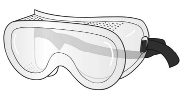
CLASSROOM ACTIVITY

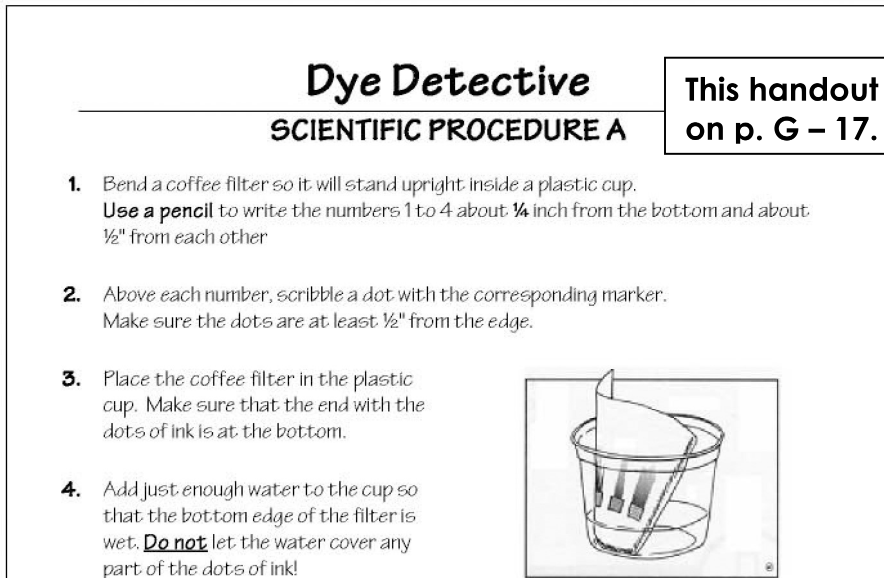
Have students follow the Scientific Procedure, working in groups of 1–3.
Procedure A is on p. G - 17; Procedure B is on p. G - 18.
Below are suggestions to help the teacher facilitate the activity.

NOTES

for procedure B:

If available, goggles are recommended for this activity.





Dye Detective

SCIENTIFIC PROCEDURE A

1. Bend a coffee filter so it will stand upright inside a plastic cup. **Use a pencil** to write the numbers 1 to 4 about ¼ inch from the bottom and about ½" from each other
2. Above each number, scribble a dot with the corresponding marker. Make sure the dots are at least ½" from the edge.
3. Place the coffee filter in the plastic cup. Make sure that the end with the dots of ink is at the bottom.
4. Add just enough water to the cup so that the bottom edge of the filter is wet. **Do not** let the water cover any part of the dots of ink!

This handout is on p. G – 17.

This activity has two procedure sheets. Procedure A uses only water and water-soluble markers. Procedure B uses water and alcohol and uses water-soluble and waterproof markers.

Running Suggestions:

- **Use a pencil** to label the filter paper. Ink will separate in this activity, and labels will be ruined if they are written in ink.
- The most common mistake students make is accidentally submerging the ink spots on their paper in the water (or alcohol). This happens when they have too much liquid in the cup or cut the strips too long.
  - Remind students to dot their papers at least ½" above the bottom edge ("finger width"). If the dots are too low, it's hard to keep the liquid from touching them.
  - Students should have just enough liquid to touch the bottom ¼" of the paper. Alternatively, they can hang their paper higher.
  - Students should carefully lower their papers with ink spots into the cups to see if they have so much water that it will cover up their spots. If they do, they should pour the water out.
- Tiny ink dots work better than big dots or smears, which don't separate as well.

- As the water runs up the paper, it tends to evaporate off the surface. This keeps it from traveling as far up. To increase the separation of colors, have students cover the tops of their cups to reduce evaporation (with an inverted, wider cup, for instance).
- Each chromatogram only takes a few minutes to run, so encourage students to try them several times (if they have supplies).
- Even after the water has reached the top of the paper, the inks are still separating. Water continues to move up the paper, carrying the inks. The extra water evaporates off the top of the paper.

Ongoing Assessment:

- What is happening to the water? Why is it moving up the paper? *The water moves up the paper against gravity. It moves up the paper due to capillary action (older students may know this).*
- What happened to the ink? What do you see? *The ink moves up the paper as the water passes over it, separating into colors.*
- How did you decide when the chromatography is done? *The chromatography is done when the colors have separated sufficiently. Alternatively, students may stop the experiment when the advancing liquid line reaches the top of the paper.*
- Based on your results, how are the markers the same and different from each other? *They create different patterns of color. However, some markers may appear to have the same colors in them. For instance, the blue from one marker may appear at the same spot on the paper from different markers, even if the markers have other different colors.*
- What effect does the alcohol have on the permanent markers? *The alcohol separates the permanent marker colors while water did not.*

Safety and Disposal Information:

- If available, goggles are recommended and should be worn by students handling isopropyl alcohol.
- Waste isopropyl alcohol may be poured down the sink drain with lots of water.
- All other materials can be thrown away as solid waste.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Did some of the pens have similar patterns?

Probably, since companies use similar inks. The distance a particular ink travels up the paper depends only on the type of ink, so if different brands of marker use the same inks, they will produce similar patterns using this technique.

Why did the water move up the paper?

The paper soaks up the water (younger grades); alternatively, the water moves up the tiny fibers in the paper through capillary action, just as it moves up the trunks of trees.

How and why did the colors move up the paper?
The water (or alcohol) carried them up the paper because the colors were able to dissolve in the water (or alcohol).

Why do some colors (or dyes) move farther than others?
Two factors affect the movement of the ink molecules: their size and their ability to dissolve in alcohol or water. Some ink molecules are larger and heavier, so they did not travel up the paper as easily. Also, those inks that didn't dissolve well stuck more to the paper, so they didn't travel as far.

For procedure A:

If the water dissolves the inks and carries them, do you think this technique would work with permanent (i.e., waterproof) markers?
Not really, because the dyes in the permanent markers do not dissolve in water. (If they did, they would easily wash away and would not be permanent.) If they don't dissolve in water, the water moves past them without separating them.

EXPLANATION

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

In this experiment, students use chemistry to separate marker inks into a recognizable pattern on a piece of paper.

Studying Mixtures
Most substances are made of a **mixture** of different chemicals. For example, many markers and pens contain mixtures of different inks, and human cells contain mixtures of many different biological molecules (like DNA, proteins, sugars, etc.).

To study mixtures, scientists perform chromatography, a technique that separates chemicals using differences in their chemical or physical properties. In this experiment, students use **paper chromatography** to separate marker inks into a recognizable pattern on a piece of paper. Each of these patterns, called **chromatograms**, corresponds to a specific brand of marker, and it can be used to identify the marker.

Paper Chromatography

In paper chromatography, scientists first place tiny spots of chemical mixtures onto pieces of paper. They then suspend the papers vertically over a liquid solution, allowing only the bottom tip of the paper to touch the liquid. The liquid rises through the paper through a process called **capillary action**. (In capillary action, tiny wood fibers in the paper, like all tiny tubes, draw liquids up against the force of gravity.) Water rises up from the roots in trees in the same way.

As the climbing liquid passes the spot of ink in the paper, it **dissolves** and carries the colored inks up the paper. However, two factors affect the speed the ink travels up the paper. First, each chemical will "stick" to the paper to a different extent, depending on its chemical properties. In a similar way, each chemical will "stick" to the liquid a certain amount, depending on how chemically similar it is to the liquid. Since the inks move at different speeds in the experiment, they will travel different distances and create a unique pattern. This unique pattern, or **chromatogram**, allows scientists to identify mixtures.

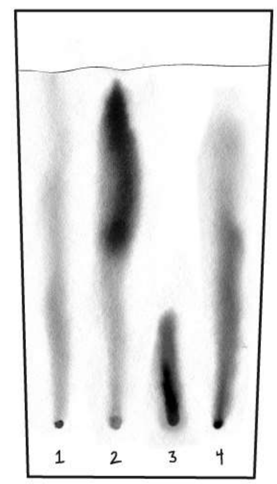


Figure 3. Sample chromatogram

In the experiment, chemicals that stick to paper and also do not dissolve well in water will tend to remain near the bottom of the paper as the water passes over them. On the other hand, chemicals that dissolve very well in water and don't really stick to the paper will travel farther up. Chemicals that fall between these extremes will travel midway up the paper.

Since black is a mixture of many colors of ink, black ink will separate into its component colors along the paper.

Other Liquids

Students may discover that water does not separate permanent marker inks. For inks that don't dissolve in water, scientists use liquids beside water. Rubbing alcohol does dissolve permanent markers, and in this activity students use rubbing alcohol to separate the colors in permanent markers.

Scientists have discovered that changing the liquid in the activity changes how the colors separate. For instance, vinegar and ammonia solutions both spread the colors out differently. Students explore the effect of different liquids in the Inquiry Extension.

Other Chromatography Processes
A powerful technique, called **gas chromatography**, uses gas to carry and separate the chemicals in a mixture. With gas chromatography, scientists can separate and identify many different mixtures, including paint chips, pharmaceuticals, and brands of lipstick, food residues, and tobacco. **Forensic scientists** often use this technique to analyze evidence left at crime scenes.

Biochemists use another chromatography technique called **gel electrophoresis** to separate and analyze **DNA**. Biochemists insert a mixture of DNA fragments in a Jell-O-like gel. Then the gel is connected to a source of electric current. The negatively charged DNA travels with the current, and the fragments of DNA are separated by size. Again, larger molecules move through the gel more slowly, while smaller molecules travel faster and farther. This creates a DNA chromatogram called a **DNA Profile**. Forensic scientists who use this process can match the DNA found at a crime scene to a suspect, just as the students match papers and ink to particular markers in this experiment.

There are many other types of chromatography, each developed to help scientists understand the world. Chromatography is an extremely useful technique that is routinely used in the top research labs in the world.

For grades 6–8:
Why do molecules stick to paper or dissolve in water? What's the difference between permanent marker inks and water-based inks? It all comes down to the amount of imbalance in their electrical charges.

Molecules with a positive side and a negative side are **polar**, even when they have an overall charge of zero. (All the molecules in this experiment are neutral, meaning that the negative charge imbalance exactly cancels the positive charge imbalance.) Polar molecules tend to dissolve in water, and, when they are colored, they make great water-based inks.

On the other hand, **non-polar** (electrically balanced) molecules do not dissolve as well in water. Permanent marker inks tend to be more non-polar.

For more on the polarity of molecules, see the Explanation section of **Salting Out.**

EXTENSIONS

Extension A: Calculate the Retention Factor

Following the activity, students can quantify their results with a simple calculation.

Extra Supplies

- 1 ruler per group

Extra Instructions

- Students measure the distance the liquid has traveled on the paper and also the distance each color of ink has traveled.
- The ink colors may separate into broad bands. Have students measure to the middle of each band.
- Use Figure 4 as a guide.
- Repeat the calculation for every separate dye on the chromatogram.

Explanation

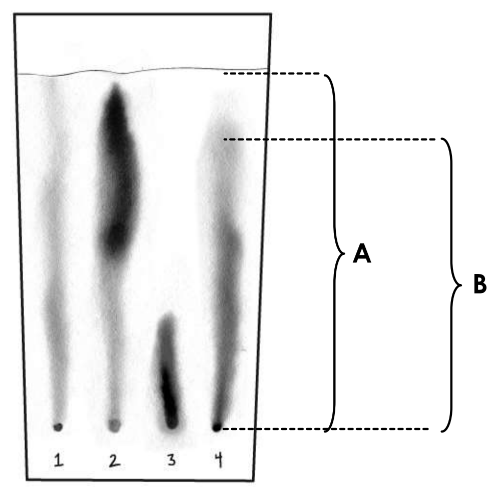
Chromatograms can be complicated and difficult to compare with each other. In order to avoid confusion, scientists measure the **retention factor** (R_f) of each ink. The R_f is the ratio of how far the ink traveled compared to how far the liquid (e.g., water or alcohol) traveled.

$$R_f = \frac{\text{distance the ink has traveled}}{\text{distance the water has traveled}}$$

R_f is always measured from where the water and ink first mixed together, as shown in Figure 4.

The retention factor is what allows scientists to compare results from different tests. The same ink, run on the same type of paper in the same solution, will always show its separate dye(s) with the same retention factor(s).

Figure 4. Chromatogram with R_f measurements shown.



A = distance ink has traveled
B = distance water has traveled
R_f = A/B

Extension B: Inquiry Opportunity—Different Liquids
Students can try different liquids and mixtures of liquids. Vinegar, ammonia, rubbing alcohol, and mixtures of alcohol/vinegar, and alcohol/ammonia produce different chromatograms.

Extra Supplies
- ❑ 1–2 permanent black markers (different brands)
- ❑ 1–2 black Flair™, Mr. Sketch™, or Vis-à-vis™ brand washable markers
- ❑ pop-top squeeze bottles with one or more of the following solutions
    - vinegar, household (¼ cup per group)
    - ammonia, household (¼ cup per group)
    - isopropyl (rubbing) alcohol (¼ cup per group)
    - 50% rubbing alcohol / 50% vinegar (¼ cup per group)
    - 50% rubbing alcohol / 50% ammonia (¼ cup per group)

CAUTION: Ammonia is irritating to eyes. In case of contact, flush eyes immediately with ample water.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

CROSS-CURRICULAR CONNECTIONS

LANGUAGE ARTS

Mystery Stories

Have students read a mystery book (e.g., Hardy Boys, Nancy Drew, Encyclopedia Brown, or Sherlock Holmes). Report on the techniques used to examine clues.

Check the newspapers for reports of real-life criminal investigations.

Have students write a mystery.

SOCIAL STUDIES

Career Connection

Interview or invite a police detective, a criminal lawyer, or a forensic specialist to talk to the class.

ART

Chromatography Art

Repeat the chromatography using entire coffee filters. Mark the filters at the centerfold and run the chromatograms. Then fold the coffee filters out from the center to make colored flowers. Attach the flowers to popsicle sticks or straws to make a bouquet.

Draw designs on filter paper, and then use chromatography to create designs. Use the finished chromatograms as paper for cards.

RESOURCES

Web – http://www.kids.union.edu/classroomActivities.htm

Lists many activities for classrooms by concept. Under chromatography, two activities link chromatography to books, *Rainbow Crow* and *The Very Hungry Caterpillar*.

Walker, Pam and Wood, Elaine, *Crime Scene Investigations: Real Life Science Activities for the Elementary Grades*

Reading level: 3rd to 6th grade

A teacher resource book containing instructions for 60 different activities related to Technology, Earth, Life, and Physical Science. Students investigate and solve crimes through scientific activities.

Carr, Mary, *One-Hour Mysteries* and *More One-Hour Mysteries*

Reading level: 4th to 8th grade

Each book provides instructions for teachers and students to solve 5 different mysteries. Focuses on logic as well as scientific principles to solve crimes

VOCABULARY

capillary action: the tendency of small tubes to draw liquid up into them, against the force of gravity, due to the attraction of water to the molecules in the sides of the tubes

chromatogram: a paper showing a mixture separated using chromatography

chromatography: a process scientists use to separate, analyze, or purify mixtures

dissolve: when the molecules of a solid separate and become completely surrounded by the molecules of a liquid

DNA: **D**eoxyribo**N**ucleic **A**cid; a long molecule found in the nucleus of a cell and shaped like a double helix; contains genetic information

DNA profile: a chromatogram of an individual's DNA, used to identify individuals or to diagnose disease

forensic scientist: scientist who studies evidence left at a crime scene

gas chromatography: process that uses heated gas to carry and separate a mixture into its component parts

gel electrophoresis: process that uses gel and electricity to separate a mixture into its component parts; used primarily for DNA, proteins, or other biological molecules

mixture: two or more substances that are mixed together but are not chemically bonded

non-polar: describes neutral molecules whose charges are electrically balanced

paper chromatography: process that uses paper and liquid to separate a mixture into its component parts

polar: describes neutral molecules with unbalanced electrical charges, i.e., a positive side and a negative side

retention factor: a ratio comparing how far a chemical travels compared to how far the liquid traveled; abbreviated R_f.

Dye Detective

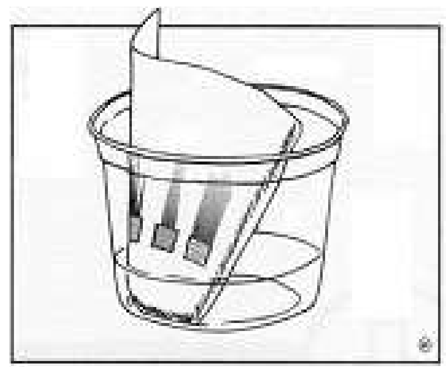
SCIENTIFIC PROCEDURE A

1. Bend a coffee filter so it will stand upright inside a plastic cup.
Use a pencil to write the numbers 1 to 4 about **¼** inch from the bottom and about ½" from each other

2. Above each number, scribble a dot with the corresponding marker.
Make sure the dots are at least ½" from the edge.

3. Place the coffee filter in the plastic cup. Make sure that the end with the dots of ink is at the bottom.

4. Add just enough water to the cup so that the bottom edge of the filter is wet. <u>**Do not**</u> let the water cover any part of the dots of ink!



Only the very end of the paper should touch the water.
DO NOT let water touch your ink spots.

5. Watch the water soak the filter until it is about an inch from reaching the top edge. Then, remove the filter from the water.

- What has happened to the dots of ink on the filter?
- How are all the stains left by the markers the same?
- How are the stains different from one another?

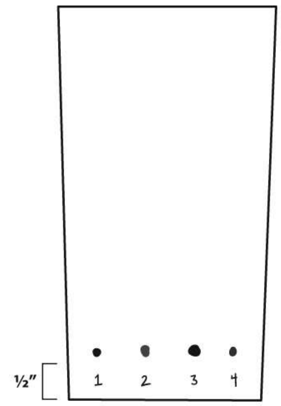
6. Set the filter aside to dry.

7. Clean up your work area.

- Follow your teacher's instructions.

Dye Detective

SCIENTIFIC PROCEDURE B



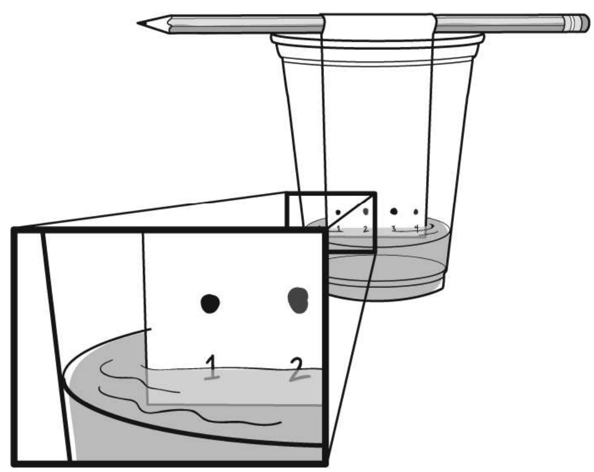
MAKE SURE the dots are at least ½" from the bottom

1. **Use a pencil**, to label two strips of filter paper "water" and "alcohol."

2. **Use a pencil**, write the numbers #1 to #4 along the bottom edge of each strip, at least ½" apart.

3. Above each number, scribble a dot with the corresponding marker. Make sure the dots are and ½" from the bottom. This ensures that the inks won't mix.

4. Tape the top of the **water filter paper** to an extra pencil. Lay the pencil across the mouth of a cup. Leave the strip hanging inside the cup.



Only the very end of the paper should touch the water. **DO NOT** let water touch your ink spots.

5. <u>Slowly</u> add water to the cup so that **only** the bottom edge of the strip is wet. <u>Do not</u> let the water cover any part of the dots of ink!

6. Watch the water soak upwards until it is about an inch from reaching the pencil. Take the pencil off the cup so that the filter paper is out of the water.
   - How has the ink on the filter paper changed?
   - How are all the stains left by the markers the same?
   - How are the stains different from one another?

7. Set the wet filter paper aside to dry. Discard the leftover water and dry the cup.

8. Tape the top of the **alcohol filter paper** to an extra pencil. Set up the cup and pencil again with the filter paper hanging down freely.

9. Slowly add **alcohol** to the cup so that **only** the bottom of the strip is wet. **Do not** let the alcohol cover any part of the ink dots!

10. Watch the alcohol soak upwards until it is about an inch from reaching the pencil. Take the pencil off the cup to stop the alcohol spreading.

- How has the ink on the filter paper changed this time?

- How are all the stains produced with the alcohol similar? How are they different from one another?

11. Allow the second strip of filter paper to dry as well. Then compare the two strips.

- Was there an ink that ran in the same kind of pattern with both water and alcohol? Which marker did it come from?

- Was there an ink that ran in two different patterns? Which marker did it come from?

- Why do some inks run differently in alcohol than in water?

12. Clean up your work area.

- Follow your teacher's instructions.

SUPPLY WORKSHEET

This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Dye Detective

Recommended group size: 1–3

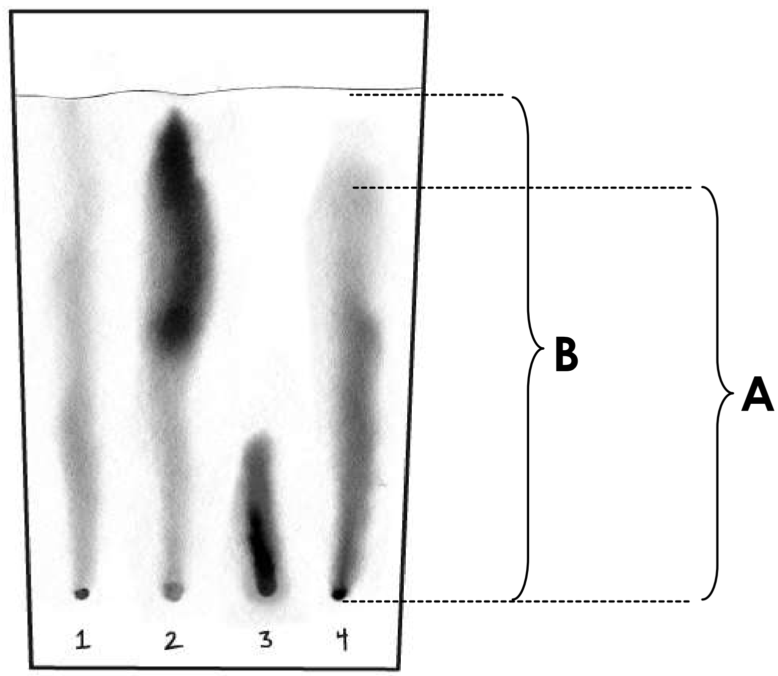
Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Procedure A			
clear, plastic cups (8 oz. or 12 oz.)	1 per group		
watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels	2–3 per group		
water-based (washable) black markers, each from a different brand (e.g., Vis-à-vis™, Flair™, or Mr. Sketch™)	3–5 per group		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
water	¼ cup per group		
long rigid object to lay across the top of cup (pencils, pens, wooden craft sticks, etc.)	1–2 per group		
Procedure B			
clear, plastic cups (8 oz. or 12 oz.)	1 per group		
watercolor paper cut into 2" x 3" strips, or cone shaped #2 size coffee filters, or 2" x 3" strips of fine-grained paper towels	2–3 per group		
water-based (washable) black markers, each from a different brand (e.g. Vis-à-vis™, Flair™, or Mr. Sketch™)	3–5 per group		
permanent (waterproof) black markers, each from a different brand (e.g., Sharpie™)	3–5 per group		
pop-top squeeze bottles (e.g., water or sports drink)	2 per group		
water	¼ cup per group		
alcohol (rubbing alcohol or isopropyl alcohol)	¼ cup per group		
long, rigid object to lay across the top of cup (pencils, pens, wooden craft sticks, etc.)	1–2 per group		
tape	1 roll per group		
Extension A			
ruler	1 per group		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Extension B			
water-based (washable) black markers, each from a different brand (e.g., Vis-à-vis™, Flair™, or Mr. Sketch™)	1–2 per group		
permanent (waterproof) black markers, each from a different brand (e.g., Sharpie™)	1–2 per group		
pop-top squeeze bottles with one or more of the following solutions o vinegar, household o ammonia, household o isopropyl (rubbing) alcohol o 50% rubbing alcohol / 50% vinegar o 50% rubbing alcohol / 50% ammonia	¼ cup each liquid per group		
Teacher Demonstration			
no additional supplies needed			

Chromatogram with retention factor (R_f) measurements shown.



A = distance ink has traveled
B = distance water has traveled
R_f = A/B

Latent Prints

Learning Objectives: *Students will learn how to dust for fingerprints. They also investigate how tiny particles of matter stick to each other, based on the electrical charges in them.*

GRADE LEVEL

4–8

SCIENCE TOPICS

Atoms and Molecules
Physical Properties
Organic and Biochemistry

PROCESS SKILLS

Comparing and Contrasting
Classifying
Organizing Data

GROUP SIZE

1–2

SNEAK PEAK inside …

ACTIVITY

Students use mechanical pencil lead to create a working fingerprint powder.

STUDENT SUPPLIES

see next page for more supplies

mechanical pencil leads
small paintbrushes
tape, paper, etc.…

ADVANCE PREPARATION

see next page for more details

cut paper in half, etc.…

OPTIONAL EXTRAS

DEMONSTRATION

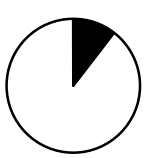
Modeling the Procedure (p. G - 25)

EXTENSIONS

Fingerprints on Other Surfaces (p. G - 29)
Test Other Powders (p. G - 30)
Catch a Thief (p. G - 30)

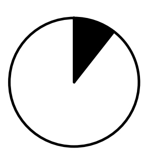
TIME REQUIRED

Advance Preparation



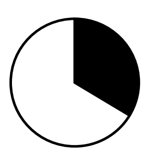
5 minutes

Set Up



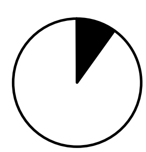
5 minutes

Activity



20 minutes

Clean Up



5 minutes

SUPPLIES

Item	Amount Needed
mechanical pencil leads	3 per group
clear tape	1 roll per group
paper (notebook or printer paper works fine)	½ sheet per group
white paper (printer paper works fine)	1 sheet per student
sealing plastic bags (e.g., Ziploc™)	1 per group
small paintbrush (e.g., watercolor brush)	1 per group
markers, pens, or other hard cylinders	1 per group
various fingerprinting surfaces—metal, clear plastic, coated cardboard, and glass work best (soda cans, 2-liter bottles, plastic water bottles, aluminum foil, glass food containers, crayon and marker boxes, etc.)	varies

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Paper:
- ❑ Cut 8 ½" x 11" notebook or printer paper in half, "hamburger style" (8½" x 5½" inches)

SETUP

For each group
- ❑ 3 sticks of mechanical pencil lead (3 sticks per group)
- ❑ roll of clear tape
- ❑ sealing plastic bag
- ❑ marker or other hard cylinder
- ❑ small paintbrush
- ❑ 5 ½" x 8 ½" paper
- ❑ white paper

At a central location (or with the teacher)
- ❑ Various fingerprinting surfaces

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

Look closely at your fingertips, then at the fingertips of the person sitting next to you. How are they similar and how are they different? Is the fingerprint pattern different between different fingers on the same hand?
Answers will vary.

Who can drink this soda without leaving a fingerprint on it? (or “use this pencil,” “dial this number on my phone”, “use my keyboard,” etc.)
Student volunteers may wear gloves, use a cloth between their finger and the object, wipe the object after use, or claim they won’t leave prints.

Why do our fingers leave prints behind? What surfaces do our fingers leave prints on?
Depending on grade level, students will give many suggestions. To provoke discussion, ask questions about a variety of surfaces—cloth, paper, metal, plastic, glass, wax paper, ice, car tires, cardboard, leather, fleece, etc.

How can we find fingerprints that are left behind?
Depending on students’ exposure to crime shows, they may have many answers, including using UV light, lasers, powders, iodine, etc. Not every method shown on TV is actually used in the real world.

Students will discover the methods behind fingerprinting crime scenes using crushed mechanical pencil lead as fingerprint powder.

TEACHER DEMONSTRATION

Modeling the Procedure
If you wish, demonstrate how to crush the graphite and how sticky the graphite powder is when spilled. You can also demonstrate proper brushing technique (lightly brushing).

Dust gently

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page G - 33, working in groups of 1–2. Below are suggestions to help the teacher facilitate the activity.

NOTES

Latent Prints

This handout is on p. G - 33.

SCIENTIFIC PROCEDURE

1. Fold your piece of paper in half. Then place it inside the plastic bag, with the folded edge down.
2. Place three pencil leads inside of the paper, then seal the bag.
3. Roll the marker over the lead until it is crushed into a fine powder.

4. Find a smooth surface, like a soda can, plastic bottle, or piece of aluminum foil. Press your finger onto the surface.
   - *Can you see your fingerprint?*
5. Open the bag carefully. Dip the paintbrush into the powder. Carefully brush the powder where you left your print.

Running Suggestions

- It takes a bit of practice to get the prints up, but most students can do it. Work with students to get it right and make allowances for those prints that don't come up right away.
- If students have dry or cold (non-sweaty) hands that don't leave great prints, have them pick up more oil by rubbing the bridge of their nose or their temples or running their fingers through their hair.
- Encourage students to keep the graphite powder in the plastic bag—it's messy and difficult to get back if it's spilled
- Tell students what they can and cannot dust (creating a "mock" crime scene helps with this) so they don't dust everything around!
- Caution students to keep their fingers powder-free, since they'll need clean fingers to leave more fingerprints.
- Students should not touch the sticky side of the tape!
- When students leave a print, make sure they remember where it is for when they later dust and lift the print. It's easy to lose the prints because they are invisible. Students can leave their prints in the corner of the surface.
- Make sure they grind the graphite well. Large chunks are not effective as fingerprint powder.

Ongoing Assessment

- What surfaces work better than others? Why do you think some work better than others?
- Are fresh fingerprints or old fingerprints easier to see?

Safety and Disposal

- Save the paintbrushes for reuse.
- All other materials may be thrown into the trash when done.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What helps the powder stick to the latent prints?
The size and type of powder particles are important. If students recognize that size is important, ask if finer powder would work better or not. If they suggest the type of powder, ask them if other powders might also work.

Are the forces of attraction between the powder and print very big or very small? How do you know?
Very small, since students can brush the powder away so easily. But the forces must still be big enough to hold the particles to the fingerprint. The cumulative action of many tiny forces is very important in chemistry.

Why didn't the powder stick to the surface the print is on? Or did it?
The powder sticks less to the surface (glass, plastic, etc.) than to the print because the surface is made of different chemicals. Forensic scientists use the difference in how chemicals stick to each other to find fingerprints.

What if I wanted to find prints on black surfaces?
Another color of fingerprint powder is necessary.

The extensions listed expand on some of the questions asked in the discussion. Following this activity with an extension helps to reinforce the concepts learned in this activity.

EXPLANATION

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

In this experiment, students learn the chemistry of fingerprinting by investigating how fingerprints stick to surfaces. They also practice "lifting" such prints off of the surface to preserve a physical record of the print.

BACKGROUND FOR ALL GRADES

Fingerprints

Fingerprints are the unique, permanent pattern of ridges and valleys on the underside of our hands. Because fingerprints can uniquely identify people, **forensic scientists** and police officers collect fingerprint evidence to understand who was present at a crime scene.

Why do people leave fingerprint evidence at all? Since a thin layer of skin oils and sweat almost always covers human hands, people often transfer a copy of their fingerprints to the smooth surfaces that they touch. Such prints, called **latent prints**, are oily, sweaty copies of the tiny ridges on each finger. The oils and sweat stick to surfaces for quite a long time before they degrade or are wiped away by another contact. Latent prints are so common that almost every metal or plastic surface that someone has touched will have some latent prints.

The Chemistry of Latent Prints

Because the sweat and oil patterns of latent prints are very faint and very small, most latent prints are invisible to the human eye. To find them, forensic scientists apply special powders that stick to the oil and moisture in the fingerprints. These powders are designed to stick to the prints but not to the surface the prints are on.

The powder sticks because the oil and sweat in fingerprints have slightly **charged molecules**. These charged molecules are attracted to other charged molecules on the surfaces you touch. This is basically the same process by which balloons can be rubbed so that they stick to a person's hair, that is, a kind of "static cling" on the molecular level.

The Power of Graphite

In this experiment, students dust their prints with a fine fingerprinting dust made from **graphite**, the form of carbon found in pencil leads. Professional grade black fingerprint powders often contain graphite, too. Graphite is a good choice for many reasons. First, the arrangement of atoms in graphite has small fluctuating charges that are attracted to the charged atoms in the fingerprint oil. Second, graphite makes very fine powders and these small dust particles tend to get physically trapped in the oil print pattern that "sticks up" from the flat surface. Third, graphite doesn't stick to metal, glass, or plastic surfaces very much. This means that when students brush over the latent print with graphite, the graphite sticks to the print but comes off the surface.

Special powders
Graphite does have some shortcomings. For example, it doesn't work very well on black surfaces, clothes, paper, or wood. Forensic scientists would use a different technique depending on the type of surface they are analyzing.

- **Colored powders—**Graphite is black and won't reveal prints on black surfaces. Grey, white, red, and other colored powders are used for different colored surfaces.
- **Fluorescent powders—**Because some fingerprints are old (i.e., dry) or very faint, very little powder will stick to them. For these prints, scientists use special fluorescent powders that give off extra light under ultraviolet radiation. The extra light coming off the prints makes it easier to photograph them as evidence.
- **Magnetic powders—**For very fragile, incomplete, or old prints, the act of brushing the powder over the print may actually destroy it. In these cases, police officers use a magnet suspended over the print. The magnet directs magnetic powder onto the print without disturbing the print.
- **Other techniques—**Forensic scientists also apply special chemicals to some prints to find them. For example, iodine gas can be passed over latent prints to turn them brown. In addition, spraying the prints with ninhydrin and heating the surface to 220°F makes the latent prints turn purple.

EXTENSIONS

Extension A: Fingerprints on Other Surfaces
Try using graphite to find fingerprints on other surfaces, such as rubber, paper, aluminum foil, cloth (scraps), wood, skin, wax paper, etc.

Extra Supplies
- porous or absorbent fingerprinting surfaces: cardboard, paper, cloth, wood, etc.
- non-sticky or bumpy fingerprinting surfaces: waxed paper, rubber, banana peels, orange peels, golf balls, window screens, skin, etc.

Extra Instructions
- Students should collect and compare the prints from the different surfaces to the prints from the surfaces in the main activity.

Explanation

These surfaces are more difficult for a few reasons. The graphite will tend to stick to paper and cardboard, so the difference between how well it sticks to the fingerprint and the surface is lessened. In addition, these porous surfaces tend to absorb the skin oils more, making the print harder to dust. Waxed paper resists the adherence of latent prints. Golf balls and rubber are textured, so the print may stick only to the exposed ridges.

Extension B: Test Other Powders
Test a variety of powders on glass, metal, or plastic surfaces.

Extra Supplies

- talc powder (preferably unscented)—works well on plastics, metals
- chalk—takes some work to make the particle size small, but works on most surfaces
- flour, cornstarch—choose a brand with a fine particle size
- dry tempera paint—a bit messy, but a very fine powder that sticks well to prints
- black paper

Extra Instructions

- Students should repeat the procedure of the main activity, except dust their prints with different powders
- When students lift their prints with the tape, they should stick their prints onto a sheet of black paper.
- Students should compare prints from this activity to the prints from the main activity.

Extension C. Catch a Thief
Set up a crime scene in your classroom. Turn your students into detectives as they develop fingerprints to try to find out who stole the object (e.g., treats, toys, etc.). Instruct your students to identify the prints of the thief and find the stolen item.

Extra Supplies

- empty plastic container
- candy, toys, or other "stolen" items you intend to share with the class
- a willing student "thief"
- stamp pads (1 per group) (optional)
- paper

Extra Instructions

- Before class, have your student accomplice put his or her fingerprints all over an empty box. It works best if he or she rubs his or her temples to get very oily fingers.
- Develop the prints on the box yourself, using the graphite powder. It's best if you do this before class, in case the prints don't develop well for some reason.
- Show students the empty plastic box. Explain to students you had some treats for them stored in the box, but now they are missing because someone in the class stole them.
- Show students the fingerprints from the box. Explain that they will use fingerprinting techniques to identify who in class stole the treats.
- Students should collect prints from everyone in class. They may either use the ink pads to collect prints or use the technique described in the main activity. The ink pads create cleaner prints, but create the risk of fingerprints being deposited all over the classroom.
- Encourage students to keep their data collection page neat and labeled.

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES

Fingerprinting History
Research Henry Faulds, Francis Galton, and William Herschel, who are commonly seen as the pioneers of fingerprinting technology.

Accuracy of Fingerprinting
Research a story in which a person was falsely identified as a criminal using fingerprint evidence. What are the problems with using fingerprinting to identify criminals?

MATHEMATICS

Sorting Surfaces
Instruct students to sort their fingerprints in order of best to worst. What surfaces gave the cleanest prints? What do these surfaces have in common? What surfaces gave the worst prints? By sorting and looking for correlations, students should see what types of surfaces are most likely to support identifiable prints.

ART

Fingerprint Pictures
Use fingerprints and ink pads to create multiple pictures.

RESOURCES

Web – http://www.fbi.gov/hq/cjisd/iafis.htm
The Integrated Automated Fingerprint Identification System, a national fingerprint and criminal history system maintained by the Federal Bureau of Investigation (FBI).

Web – http://www.hcso.tampa.fl.us/SOD/ffingerprintid.htm
A Web site on fingerprint identification run by the Federal Bureau of Investigation (FBI).

Web – http://www.ridgesandfurrows.homestead.com/early_pioneers.html
Web site lists the biographies of early pioneers of the study of fingerprinting, including Henry Faulds, Francis Galton, and Sir William Herschel.

Web – http://www.bbc.co.uk/history/historic_figures/faulds_henry.shtml
Details the story of Henry Faulds, Francis Galton, and Sir William Herschel and the conflicting claims of who was responsible for first using fingerprinting as a means of identification.

Emberly, Ed, *Ed Emberly's Fingerprint Drawing Book*
Reading level: all ages
An amazing number of drawings and figures created using fingerprints and a pen.

Jones, Charlotte, *Fingerprints and Talking Bones*
Reading level: 5th to 8th grade
Never gory or gross and often even funny, especially when explaining things such as the reason police analyze a murder victim's stomach contents. Includes a glossary, cool crime facts, and a bibliography.

***Fingerprinting*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science**
Reading level: 4th to 8th grade
Detailed plans for three class sessions, fully supported with handouts and answer keys, including fingerprint samples. Recommended by NSTA.

VOCABULARY

charged molecules: molecules that have small positive and small negative charges

fingerprint: unique, permanent pattern of ridges and valleys on the underside of a finger

forensic scientist: scientist who analyzes evidence to solve crimes

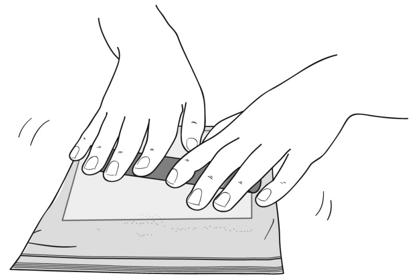
graphite: a form of carbon used in pencils

latent print: a fingerprint that is present but not visible

Latent Prints

SCIENTIFIC PROCEDURE

1. Fold the piece of paper in half. Then place it inside the plastic bag, with the folded edge down.



2. Place three mechanical pencil refills between the two halves of the folded paper. Seal the bag tightly.
3. Use the sides of a round marker like a rolling pin; roll over the bag until the pencil refills are crushed into a fine graphite powder.
4. Find a smooth surface, like a soda can, plastic bottle, or piece of aluminum foil. Press your finger onto the surface.
    - *Can you see your fingerprint?*
5. Open the bag carefully. Dip the paintbrush into the graphite powder. Carefully brush the powder where you left your print.
    - *Now can you see your fingerprint?*

6. Press a piece of clear tape over your print. Rub the tape to make it stick.
7. Pull off the tape with your print and stick it onto a piece of white paper.
    - *What does your print look like?*
8. Label the print with the name of the surface you used to make your print.
9. Repeat steps 4 through 8 with other surfaces.
10. Clean up your area.
    - *Follow your teacher's directions.*

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Latent Prints

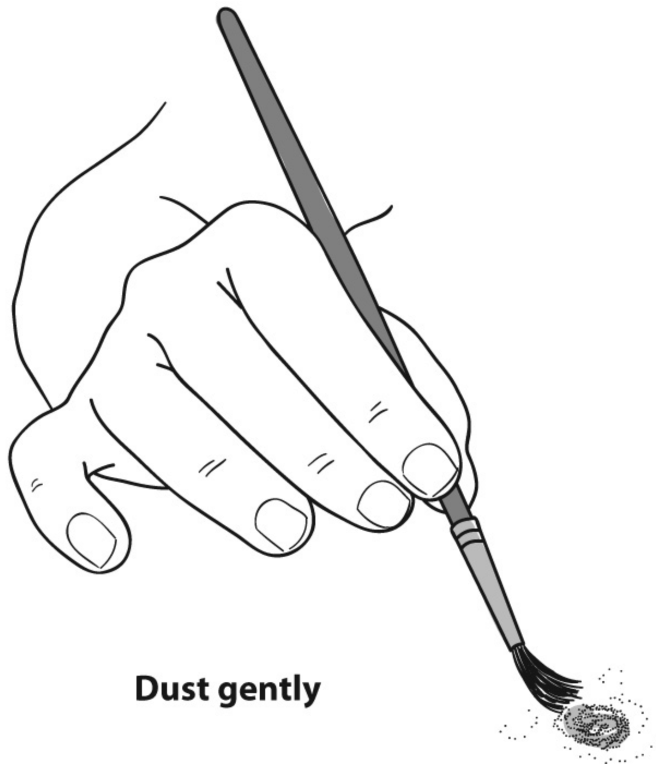
Recommended group size: 1–2

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
mechanical pencil leads	3 per group		
clear tape	1 roll per group		
paper (notebook or printer paper works fine)	½ sheet per student		
sealing plastic bags (e.g., Ziploc™)	1 per group		
small paintbrush (e.g., watercolor brush)	1 per group		
markers, pens, or other hard cylinders	1 per group		
various fingerprinting surfaces—metal, clear plastic, coated cardboard, and glass work best (soda cans, 2-liter bottles, plastic water bottles, aluminum foil, glass food containers, crayon and marker boxes, etc.)	varies		
white paper	1 sheet per student		
Extension A			
porous or absorbent fingerprinting surfaces: cardboard, paper, cloth, wood, etc.	varies		
non-sticky or bumpy fingerprinting surfaces: waxed paper, rubber, banana peels, orange peels, golf balls, window screens, skin, etc.	varies		
Extension B			
talc powder (preferably unscented	¼ cup per group		
chalk	¼ cup per group		
flour, cornstarch	¼ cup per group		
dry tempera paint	¼ cup per group		
black paper	1 sheet per student		

Supply Worksheet continues on next page.

Extension C			
empty plastic container	1 per class		
candy, toys, or other "stolen items" the class can share	varies		
a willing student culprit	1 per class		
stamp pads (optional)	1 per group		
Teacher Demonstration			
no extra materials needed			



Dust gently

Lost Labels

Learning Objectives: *Students collect and analyze data to identify substances.*

GRADE LEVEL

3–8

SCIENCE TOPICS

Physical Properties
Techniques
Chemical Reactions

PROCESS SKILLS

Measuring
Hypothesizing
Inferring
Evaluating

GROUP SIZE

1–4

SNEAK PEAK inside …

ACTIVITY

Students conduct chemical and physical tests on unknown white powders.

STUDENT SUPPLIES

see next page for more supplies

various white powders
plastic cups and spoons
various liquids to test powders, etc.…

ADVANCE PREPARATION

see next page for more details

Cut up egg cartons.
Fill ice cube trays with white powders.
Prepare test solutions, etc.…

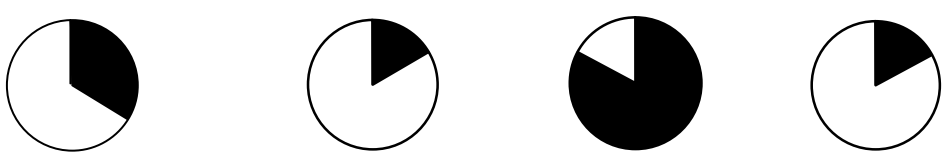
OPTIONAL EXTRAS

DEMONSTRATION
Modeling the Procedure (p. G - 42)
Salt and Sugar Solubility (p. G - 42)
Salt and Sugar Conductivity (p. G - 43)

EXTENSION
Guess My Powder! (p. G - 49)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up



20 minutes	10 minutes	50 minutes	10 minutes

SUPPLIES

Notes on activity setup:

The instructions assume your students will use 6 different tests to identify 12 different powders. For a shorter activity, you may choose to use fewer tests to identify fewer powders. To make an abbreviated version of the activity, see the following pages:

- Use 3 tests to identify 8 powders (p. G - 53)
- Use 2 tests to identify 5 powders (p. G - 54)
- Use 2 tests to identify 6 powders (p. G - 54)

In addition, there are different ways 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 of 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. If students investigate all of the powders themselves in this way, they will take over twice as long to test them. But they probably get more out of the experience.

On the other hand, student stations are easier to set up, require fewer materials, but require more management as students rotate.

Item **(this list assumes you will be testing all 12 powders; fewer supplies are needed when testing fewer powders)**	**Amount Needed**
corn starch	1 tablespoon per group
granulated sugar	1 tablespoon per group
baking powder	1 tablespoon per group
cream of tartar	1 tablespoon per group
baking soda	1 tablespoon per group
table salt	1 tablespoon per group
laundry detergent (must contain sodium carbonate—available in grocery stores)	1 tablespoon per group
Epsom salts	1 tablespoon per group
dry milk powder	1 tablespoon per group
baby powder	1 tablespoon per group
plaster of Paris	1 tablespoon per group
Alka-Seltzer tablets	1 tablespoon per group
ice cube trays (to distribute powders)	1 per group
small plastic cup (for mixing)	1 per station or group

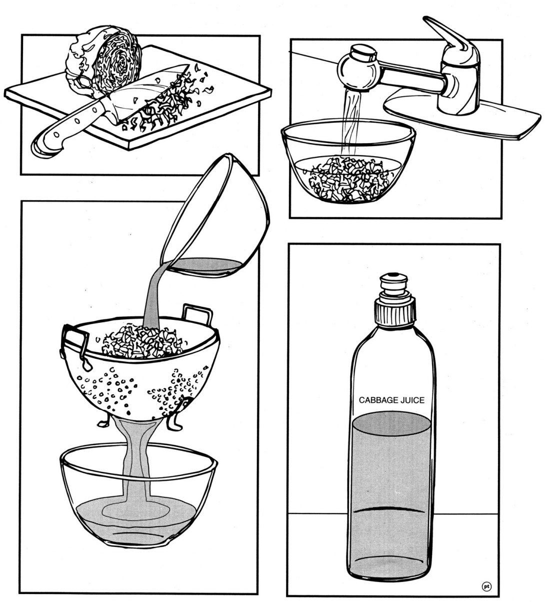
plastic spoons (for powders)	1–12 per station or group
plastic spoon (for mixing)	1 per station or group
Styrofoam or plastic egg carton, preferably white in color	1 per 3–4 stations or groups
pop-top squeeze bottles (e.g., water or sports drink) 6 oz. or larger	1–4 per station
vinegar	¼ cup per station or group
tincture of iodine	2 teaspoons per class
red cabbage	¼ cup per station or group
water	2 cups per station or group
toothpicks	10–12 per station or group
magnifying glasses (optional)	1 per station or group
paper towels	1 roll per station or group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Please see the note on activity setup above.

First CHOOSE how many tests your students will perform. All six tests will identify all 12 powders, but fewer tests still identify many powders. For instance, only two tests (iodine and cabbage) will identify up to six powders. See pages G - 48 to G - 50 for more information.



Supplies Preparation
Cabbage Juice Indicator:

- ❑ Finely chop 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 is to preserve the cabbage juice from mold).
- ❑ Store the purple water ("cabbage juice") in a labeled container in the refrigerator until ready for use. It does not need to be refrigerated on day of use.
- ❑ Dispose of solid cabbage as you would other vegetable scraps.

Iodine Solution:

- Add 1 teaspoon of tincture of iodine to 2 cups of water.
- Divide this solution into pop-top squeeze bottles.
- Use masking tape and permanent marker to label the bottles "iodine solution."

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

Alka-Seltzer:

- Put the tablets in a piece of paper folded in half. Crush with a jar or rolling pin.

Egg Cartons:

- Use scissors to cut each egg carton into four pieces, so each piece has three egg wells.
- Students will use these wells for the iodine, cabbage juice, and vinegar tests.
- In place of egg cartons, white ice cube trays will also work. Don't attempt to cut the ice cube trays, however.

Water:

- Fill pop-top squeeze bottles with room temperature water.
- Label these bottles "water."

Vinegar:

- Fill pop-top squeeze bottles with vinegar.
- Label these bottles "vinegar."

Ice Cube Trays of Powders:

- Use the masking tape and permanent marker to label up to 12 wells of ice cube trays with the numbers 1–12.
- Use the masking tape and permanent marker to label up to 12 plastic spoons with the numbers 1–12.
- Record which powder is which number.
- Add about one tablespoon of each powder into its corresponding well.
- Put the correct numbered spoon in each well.

Properties of Powders Chart:

- Make copies to place at each station.
- You may choose to laminate these.

Notes and Hints

Laundry Detergent: The detergent must contain sodium carbonate (also called washing soda). Check the label. Try out these detergents first: Arm & Hammer Fabricare, BioKleen, Seventh Generation.

SETUP

For each group

- ❑ vinegar in pop-top squeeze bottle
- ❑ cabbage juice in pop-top squeeze bottle
- ❑ iodine solution in pop-top squeeze bottle
- ❑ water in pop-top squeeze bottle
- ❑ cut Styrofoam or plastic egg carton (ice cube trays as alternative) (to be shared by several stations)
- ❑ ice cube tray with powders
- ❑ 1 empty plastic cup
- ❑ 1 plastic spoon
- ❑ paper towels
- ❑ Properties of Powders Chart

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

Tell the students the following story (or make up your own, better story!):
A woman owns a cabin in the mountains. The only cupboards are at floor level, so she keeps her household supplies in labeled jars to protect them from moisture, mice, and insects. Unfortunately, some pipes burst and flooded the cupboards, washing the labels off all the jars. She has given us samples and would like us to figure out what is in each jar.

We know what the twelve powders are, and we know some of their properties. By conducting chemical tests we should be able to determine which powder is which.

What ideas do you have for testing these powders?
Depending on the students' experience, they may suggest many tests.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Modeling the Procedure

You may wish to discuss with students the various procedures they will use to test and identify the different powders.

For the Physical Properties Test, discuss the characteristics that can help distinguish one powder from another.

For the Vinegar Test, Cabbage Juice Test, and Iodine Test, show students the amount of powder they need to use—only a pea-sized amount.

For the Temperature Test and Solubility Test, students need to add a bit more powder. If students do the Temperature test first, and the powder dissolves completely, then they don't need to do the Solubility Test since they know the powder will dissolve.

The Powder Identification Chart lists the properties for all twelve different powders. Examine this chart with students to make sure they understand how to use it. Also, if you are not using all 12 powders, students can cross out the powders that are not included.

Salt and Sugar Solubility

This demonstration is best done after the activity, assuming the activity included both salt and sugar.

Salt and sugar give the same results for all tests, so a further test is required to tell them apart. Students may suggest tasting powders, but this is not advisable since food items may be contaminated by other, poisonous substances in the lab.

Compared to cold water, hot water will dissolve a much larger amount of sugar. This is not true for salt—both cold and hot water will dissolve about the same amount. This difference can be used to distinguish salt from sugar.

Supplies

- ❑ two microwaveable cups or jars
- ❑ water (at room temperature or colder)
- ❑ salt
- ❑ sugar
- ❑ two plastic spoons
- ❑ microwave or source of very hot water (microwave water to boiling beforehand and store in a thermos)

Demonstration

- Add two spoonfuls of water to each cup.
- Add one heaping spoonful of salt to one cup and one heaping spoonful of sugar to the other cup.
- Stir to dissolve each powder as much as possible.
- Microwave both cups for 10–30 seconds, taking them out to swirl the contents after the water starts to boil. (If a microwave is not available, add very hot water to both cups and swirl the contents.)
- The sugar should all dissolve in the water while some of the salt remains.

Explanation

Salt and sugar can both dissolve in water at room temperature, but sugar can dissolve at much higher concentrations in hot water than in cold. In contrast, salt dissolves to the same degree in both hot and cold water (this is actually a rather interesting and unusual property of common table salt). Students might suggest testing other powders with this simple temperature comparison.

Salt and Sugar Conductivity

You can also demonstrate how to distinguish salt and sugar by their conductivity. Salt will conduct electricity (allowing a light bulb to light) and sugar will not conduct electricity (and the light bulb will not light).

Supplies

- two small glass jars (e.g., baby food jars)
- two batteries, AA size or larger
- three wires
- light bulb in socket with connectors
- alligator clips
- water
- plastic spoon
- sugar
- salt

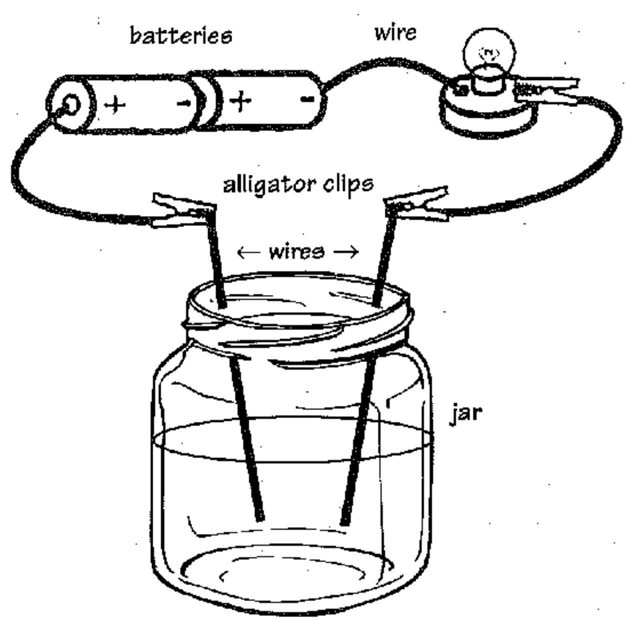


Figure 1 Sample conductivity set up. The wires in the solution and connected to the alligator clips are bare, exposed wires.

Demonstration

- Add about 1 inch of water to the jar.
- Add spoonfuls of sugar or salt to the water until no more dissolves.
- Set up the wires, clips, batteries, and light bulb according to the diagram.
- Place the wire leads in the solution. Don't let the wires touch each other.
- Ask the students to observe the jar. Do bubbles form at either of the wires? Are any changes visible in the wires? Does the light bulb glow? Does the solution change color?

Explanation

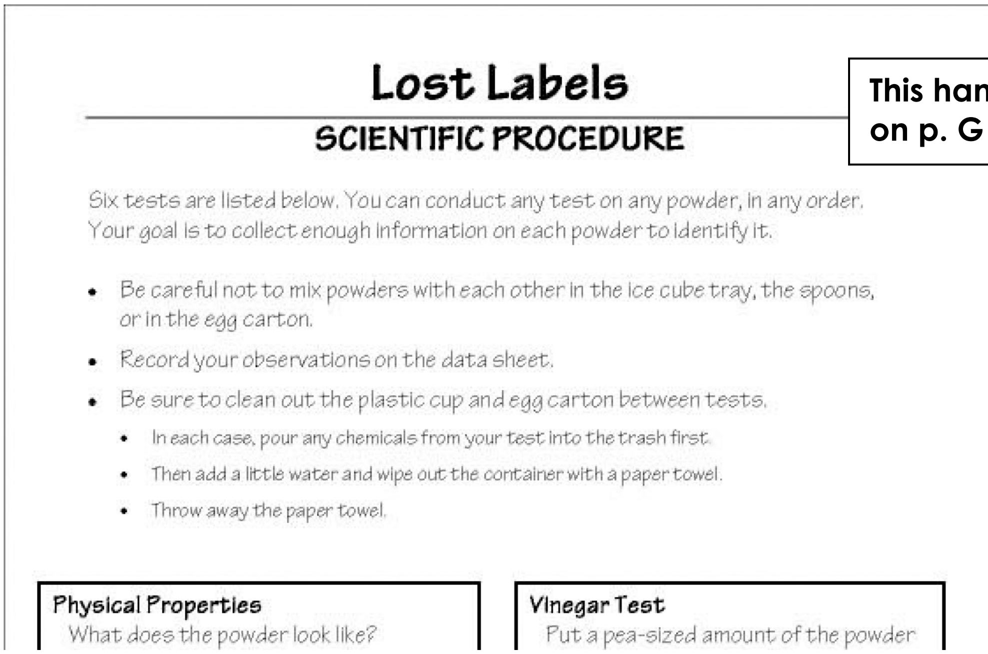
When salt dissolves in water, its molecules break apart into **ions**, small charged particles. These ions are capable of carrying a charge and can thus carry electricity. When sugar dissolves in water, its molecules separate from each other, but they do not break apart into ions. For this reason, sugar cannot conduct electricity.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page G - 55, working in groups of 1–4. Below are suggestions to help the teacher facilitate the activity.

NOTES

This handout is on p. G - 55.



Lost Labels

SCIENTIFIC PROCEDURE

Six tests are listed below. You can conduct any test on any powder, in any order. Your goal is to collect enough information on each powder to identify it.

- Be careful not to mix powders with each other in the ice cube tray, the spoons, or in the egg carton.
- Record your observations on the data sheet.
- Be sure to clean out the plastic cup and egg carton between tests.
  - In each case, pour any chemicals from your test into the trash first.
  - Then add a little water and wipe out the container with a paper towel.
  - Throw away the paper towel.

Physical Properties
What does the powder look like?

Vinegar Test
Put a pea-sized amount of the powder

Running Suggestions

- Depending on age and skill level of students, each group can identify one powder, a few powders, or all twelve. Set out a number of powders appropriate for your students.

CAUTION: Plaster of Paris clogs drains!!! If you use plaster of Paris in the activity, then:

Caution students to treat all powders as if they cannot be poured down the drain!

Instruct students to rinse their cups and egg cartons with a little water and then wipe them out with a paper towel. They should throw the paper towel away.

- 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, and Cabbage Juice Test.
- If you include both sugar and salt, students won't be able to identify them (see the Teacher Demonstration for info on identifying

them). It's a great way to spark student inquiry or a discussion of how they might be identified.

- If your students have a lot of experience with related activities, they can devise their own tests to identify the powders. Advanced and experienced students can compare notes with each other and make educated guesses. Remind students to create an organized table to keep track of all their results.

Ongoing Assessment Questions

- When students do the vinegar test, ask them what gas they think is in the bubbles and why they form. *(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 and also in baking powder.)* (Remind students of the activity, **Foam Peanuts**, if they have done it.)
- When students do the temperature 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; for some powders, this energy change is big enough to feel.)* (Remind students of the activity, **Matter of Degree**, if they have done it.)
- 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).* (Remind students of the activity, **Of Cabbages and Kings**, if they have done it.)
- Listen to students' reasoning when they identify the powders. They should refer to the Properties Chart and to their notes when identifying a powder.

Safety and Disposal Information

- If you include plaster of Paris in the activity, do not allow students to put it 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.
- Students should wear safety goggles if possible.

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 and may stain skin or clothing.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

List the numbers for each mystery powder on the board and have each group come up and write their identification for each powder. If there are conflicting results, you can discuss how each group came to the conclusion that they did.

What reasoning did you use to identify the powders?
Answers will vary. The results of each test narrow down the choices for the identity of the powders. In some cases, a powder can be identified with a single test (cream of tartar). In other cases, all six tests are required to identify a powder (baking soda vs. baking powder, for instance). In one particularly difficult case (sugar vs. salt) an extra test is required to identify the powders (see the Teacher Demonstration).

Which tests used chemical changes to identify powders? How do you know?
The Vinegar Test, Iodine Test, and Cabbage Juice Test all used chemical changes. Evidence of a chemical change can include a change in color or formation of bubbles.

Which tests used physical changes to identify powders? How do you know?
The Temperature Test and Solubility Test use physical properties. These don't create new substances. Looking at the physical properties of the powder (grain size, crystal formation, smell) is also not a chemical change.

What powders were easy to determine?
Alka-Seltzer bubbles with everything and is easy to spot. Cream of tartar is the only one that turns red with cabbage juice.

What powders were difficult to determine?
Baking soda, baking powder, and plaster of Paris don't show much of a temperature change, so they can be mistaken for other powders. Sugar and salt have the same results for all tests, so cannot be determined.

After discussing the results for the powders, perform the demonstration to determine which of the powders is salt and which is sugar.

EXPLANATION

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 each powder.

Physical Properties

Each powder is similar in color and composition, but students should still be able to find differences (especially if they have magnifying glasses). For instance, all of the powders are white, but 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**; they appear shiny on the flat surfaces of the crystal. 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**.

Vinegar Test

Several of the powders contain some form of the chemical **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.

Iodine Test

Detergent is designed to remove stains, so the iodine fades when it is mixed with detergent. Milk 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.

Cornstarch and baking powder (which contains starch) will both turn blue or black. This is because starch and iodine react to form a blue or black compound.

For a more in-depth explanation of the reaction of starch and iodine, see the Explanation section of **Foam Peanuts**.

Cabbage Test
Cabbage juice is an **indicator** and changes color depending on whether it is with an **acid** or a **base**. 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.

For a more in-depth explanation of acid base indicators, see the Explanation section of **Of Cabbages and Kings**.

Temperature Test
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 is strongly endothermic; baking powder and baking soda are only slightly endothermic. Detergent is very exothermic; plaster of Paris is slightly exothermic.

For a more in-depth explanation of chemical temperature change, see the Explanation section of **Matter of Degree**.

Solubility Test
Alka-Seltzer, Epsom salts, salt, and sugar all **dissolve** in water very 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, and all create uniform mixtures (the milk powder contains some solids that dissolve and some that don't).

EXTENSIONS

Extension A: Guess My Powder!
Students use their knowledge of chemical properties to play a game. This can be done as a class or in partners.

Extra Instructions
- One student, or the teacher, thinks of a chemical the students have identified and writes it on a hidden piece of paper.
- Other students ask yes or no questions. For instance, "Does it dissolve completely in water?"
- After answering questions, students guess the identity of the chemical.

Explanation
The game Guess Who? uses cards with people's faces printed on them. Players are challenged to identify a person based on their characteristics.

CROSS-CURRICULAR CONNECTIONS

LANGUAGE ARTS

Write a Mystery Compound Story
Students can write a story that involves the identification of a mystery compound.

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. Use one of the supplied resources, or find your own, as a starting place.

RESOURCES

Web – http://www.fi.edu/tfi/units/life/classify/classify.html
This Web site has many ideas for classification exercises using plants and animals. It suggests properties to use to group species. Lessons can be used for all ages.

Web – http://www.linnean.org/
The Linnean Society of London is concerned with taxonomy, which involves the examination and collection of a wide range of scientific evidence for accurate identification that is essential to any research. The Society finds much importance in identification of species for biodiversity conservation. Information about Carl Linnaeus, the founder of modern taxonomy, can be found on the site by choosing History from the main page.

Watts, Tom, *Pacific Coast Tree Finder*
Reading level: 3rd grade to adult
This is a classic key to identifying the native trees of the Pacific Coast, from British Columbia to Baja California. It uses characteristics such as leaf shape, tree height, and geographical location to determine the species of tree. It also includes pictures for easier identification. This book uses a dichotomous key format for accurate identification. The Finders series of pocket guides also includes guides to identify flowers, berries, mammals, and ferns.

Dussling, Jennifer, *Looking at Rocks*
Reading level: 1st grade to 4th grade
This is a great introduction to rocks and rock hounding. The pictures are clear and enhance the text, which is written at a good level for beginning readers.

VOCABULARY

acid: a compound with an excess of available hydrogen ions; often sour in taste

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-}

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

lactose sugar found in milk products

powder: composed of particles that are too small to be seen easily

Lost Labels

POWDER IDENTIFICATION CHART

Powder	Physical Properties	Vinegar Test	Iodine Test	Cabbage Test	Temp. Test	Solubility Test
Alka-Seltzer	coarse, irregular chunks	bubbles	orange-brown, bubbles	stays purple, bubbles	stays same temp	yes, bubbles
baby powder	powder, may have a smell	no bubbles	orange-brown	stays purple	stays same temp	no
baking powder	fine powder	bubbles	black, bubbles	blue, bubbles	colder	a little
baking soda	fine powder	bubbles	orange-brown	blue	colder	a little
cream of tartar	fine powder	no bubbles	orange-brown	red	stays same temp	a little
detergent	coarse, irregular chunks	bubbles	orange-brown color fades	green	warmer	a little
Epsom salts	small, sharp edged crystals	no bubbles	orange-brown	stays purple	colder	yes
milk powder	fine powder	no bubbles	orange-brown color fades	stays purple	stays same temp	milky
plaster of Paris	fine powder	bubbles	orange-brown	stays purple	warmer	paste
salt	small, sharp edged crystals	no bubbles	orange-brown	stays purple	stays same temp	yes
starch	fine powder	no bubbles	black	stays purple	stays same temp	paste
sugar	small, sharp edged crystals	no bubbles	orange-brown	stays purple	stays same temp	yes

Lost Labels

THESE 3 TESTS IDENTIFY 8 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

Lost Labels

THESE 2 TESTS IDENTIFY 5 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 2 TESTS IDENTIFY 6 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

Lost Labels

SCIENTIFIC PROCEDURE

Six tests are listed below. You can conduct any test, on any powder, in any order. Your goal is to collect enough information on each powder to identify it.

- Be careful not to mix powders with each other in the ice cube tray, the spoons, or in the egg carton.
- Record your observations on the data sheet.
- Be sure to clean out the plastic cup and egg carton between tests.
  - In each case, pour any chemicals from your test into the trash first.
  - Then add a little water and wipe out the container with a paper towel.
  - Throw away the paper towel.

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 in a well of the egg carton.
Add ¼ spoonful of vinegar.
Stir with a toothpick.
What happens?

Cabbage Juice Test

Put a pea-sized amount of the powder in a well of the egg carton.
Add ¼ spoonful of cabbage juice.
Stir with a toothpick.
What happens?

Iodine Test

Put a pea-sized amount of the powder in a well of the egg carton.
Add ¼ spoonful of iodine solution.
Stir with a toothpick.
What happens?

Temperature Test

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

Solubility Test

Add one spoonful of water to the plastic cup.
Add ½ spoonful of powder to the water.
Mix with a toothpick.
Does the powder dissolve in the water?

Lost Labels

DATA COLLECTION SHEET

Powder (write your prediction under the number)	Physical Properties	Vinegar Test	Iodine Test	Cabbage Test	Temp. Test	Solubility Test
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Lost Labels

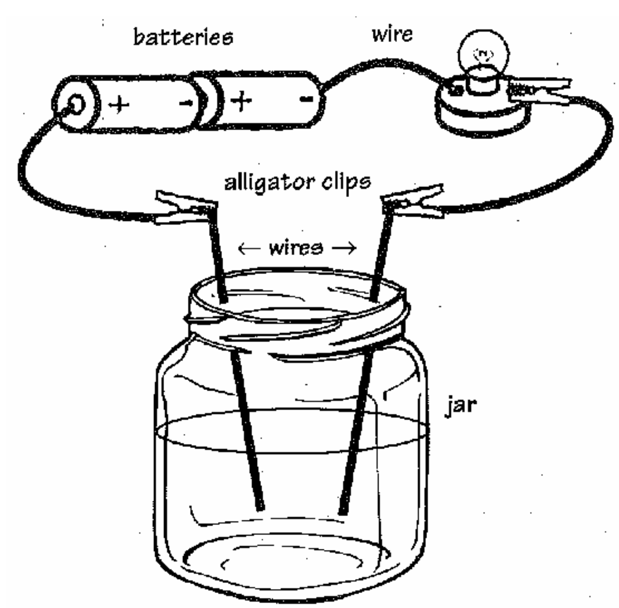
Recommended group size: 1–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
note: This list assumes you will be testing all 12 powders; modify supplies as needed when testing fewer powders			
cornstarch	1 tablespoon per group		
granulated sugar	1 tablespoon per group		
baking powder	1 tablespoon per group		
cream of tartar	1 tablespoon per group		
baking soda	1 tablespoon per group		
table salt	1 tablespoon per group		
laundry detergent (must contain sodium carbonate—available in grocery stores)	1 tablespoon per group		
Epsom salts	1 tablespoon per group		
dry milk powder	1 tablespoon per group		
baby powder	1 tablespoon per group		
plaster of Paris	1 tablespoon per group		
Alka-Seltzer tablets	1 tablespoon per group		
ice cube trays (to distribute powders)	1 per group		
small plastic cup (for mixing)	1 per station or group		
plastic spoons (for powders)	1–12 per station or group		
plastic spoon (for mixing)	1 per station or group		
Styrofoam or plastic egg carton, preferably white in color	1 per 3–4 stations or groups		
pop-top squeeze bottles (e.g., water or sports drink) 6 oz. or larger	1–4 per station		
vinegar	¼ cup per station or group		
tincture of iodine	2 tsp per class		
red cabbage	¼ cup per station or group		
water	2 cups per station or group		
toothpicks	10–12 per station or group		
magnifying glasses (optional)	1 per station or group		
paper towels	1 roll per station or group		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Extension A			
no extra supplies needed			
Teacher Demonstration			
Modeling the Procedure			
no extra supplies needed			
Salt and Sugar Solubility			
microwaveable cups or jars	2 cups or jars		
water (at room temperature or colder)	¼ cup		
salt	heaping spoonful		
sugar	heaping spoonful		
plastic spoons	2 spoons		
microwave or source of very hot water (microwave water to boiling beforehand and store in a thermos)			
Salt and Sugar Conductivity			
small glass jars (e.g., baby food jars)	2 for class		
batteries, AA size or larger	2 for class		
wires	3 or more depending on set up		
light bulb in socket with connectors	1 for class		
alligator clips	3 or more depending on set up		
water	¼ cup		
plastic spoon	1 for class		
sugar	¼ cup		
salt	¼ cup		



El caso de la tinta distinta

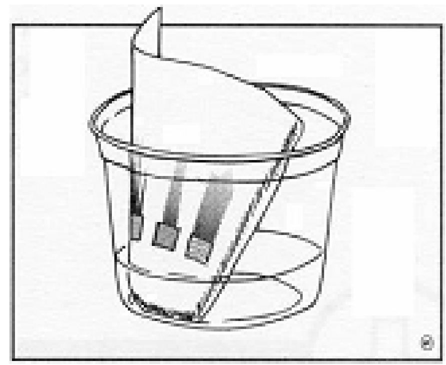
PROCEDIMIENTO CIENTÍFICO A

1. Dobla un filtro de café de manera que se sostenga verticalmente dentro del vaso plástico. **Usa un lápiz** para escribir los números del #1 al #4 a **¼ de pulgada** del borde inferior del filtro y dejando una distancia de ½" entre número y número.

2. Coloca un punto encima de cada número utilizando el marcador correspondiente. Asegúrate de pintar los puntos por lo menos a ½" del borde inferior del filtro.

3. Coloca el filtro de café en el vaso de plástico. Asegúrate que los puntos de tinta estén hacia el fondo del vaso.

4. Agrega al vaso sólo el agua suficiente para mojar el borde inferior del filtro. No dejes que el agua toque los puntos de tinta.



Solamente el borde inferior del papel debe tocar el agua. **NO DEJES** que el agua toque los puntos de tinta.

5. Observa cómo el filtro absorbe el agua hasta que llegue alrededor de una pulgada del borde superior. Luego saca el filtro del agua.
   - ¿Qué sucedió con los puntos de tinta del filtro?
   - ¿En qué son iguales todas las manchas que dejaron de los marcadores?
   - ¿En qué son diferentes las manchas unas de otras?

6. Coloca el filtro a un lado para que se seque.

7. Limpia tu área de trabajo.
   - Sigue las instrucciones de tu maestro(a).

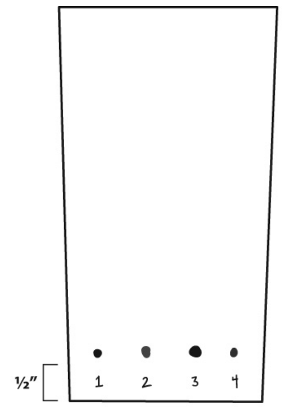
El caso de la tinta distinta

PROCEDIMIENTO CIENTÍFICO B

1. **Usa un lápiz** para macar dos tiras de filtro con las palabras "agua" y "alcohol."

2. **Usa un lápiz** para escribir los números del #1 al #4 en el borde inferior de cada tira, dejando una distancia de ½" entre número y número.

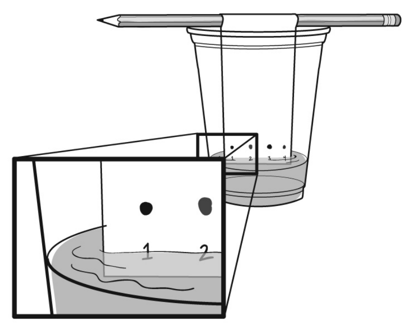
3. Encima de cada número pinta un punto con el marcador correspondiente. Asegúrate de pintar los puntos por lo menos a ½" del borde. Esto asegurará que las tintas no se mezclen.



Asegúrate que los puntos estén al menos a ½ pulgada del fondo.

4. Asegura con cinta adhesiva la parte superior de la **tira de filtro de agua** a un lápiz extra. Atraviesa el lápiz sobre la boca un vaso. Deja que la tira cuelgue dentro del vaso.

5. <u>Lentamente</u> agrega agua en el vaso para que **sólo** la parte inferior de la tira se moje. ¡**No dejes** que el agua toque la tinta!



Solamente el borde inferior debe tocar el agua. **No dejes** que el agua toque los puntos de tinta.

6. Observa cómo el filtro absorbe el agua, hasta que falte una pulgada para que el agua llegue al lápiz. Quita el lápiz del vaso para que el filtro no toque más el agua.
   - ¿Cómo ha cambiado la tinta del filtro de papel?
   - ¿En qué son iguales todas las manchas que dejaron los marcadores?
   - ¿En qué son diferentes las manchas unas de otras?

7. Coloca el filtro a un lado para que se seque. Descarta el agua restante y seca el vaso.

8. Asegura con cinta adhesiva la parte superior de la **tira de filtro de alcohol** a un lápiz. Coloca el vaso y el lápiz de la misma manera para que el filtro cuelgue dentro del vaso.

9. Lentamente agrega **alcohol** en el vaso para que sólo la parte inferior de la tira se moje. ¡**No dejes** que el alcohol toque los puntos de tinta!

10. Observa cómo el filtro absorbe el alcohol, hasta que falte una pulgada para que el alcohol llegue al lápiz. Quita el lápiz del vaso para que el alcohol no se siga absorbiendo.

    - ¿Cómo ha cambiado la tinta del filtro esta vez?
    - ¿En qué son iguales todas las manchas producidas por el alcohol?
    - ¿En qué son diferentes las manchas unas de otras?

11. Deja secar este filtro de papel también. Luego compara los dos filtros.

    - ¿Hubo alguna tinta que se diluyera en el mismo tipo de patrón tanto con el agua como con el alcohol ? ¿De cuál marcador?
    - ¿Hubo alguna tinta que se diluyera en dos patrones diferentes? ¿De cuál marcador?
    - ¿Por qué algunas tintas actúan diferente en el alcohol que en el agua?

12. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

¡Que huellas tan bellas!

PROCEDIMIENTO CIENTÍFICO

1. Dobla el papel por la mitad y colócalo dentro de una bolsa de plástico, con el borde doblado hacia abajo.

2. Coloca tres minas de lápiz mecánico dentro del papel. Cierra bien la bolsa.
3. Utiliza un marcador como si fuera un rodillo. Rueda el marcador sobre la bolsa, presionndo las minas hasta formar un polvo fino.
4. Encuentra una superficie lisa, como una lata de soda, una botella de plástico o un pedazo de papel aluminio. Presiona tu dedo contra la superficie.
   - ¿Puedes ver tu huella digital?
5. Abre la bolsa cuidadosamente. Impregna el pincel con el polvo. Con cuidado pasa el pincel lleno de polvo sobre la superficie donde dejaste tu huella.
   - ¿Puedes ver tu huella ahora?

6. Presiona un pedazo de cinta adhesiva transparente sobre tu huella. Frótalo para que se pegue.
7. Jala la cinta adhesiva con tu huella y pégala en un papel blanco.
   - ¿Cómo se ve la huella?
8. Marca la huella con el nombre del objeto de donde obtuviste la huella.
9. Repite los pasos del 4 al 8 con otras superficies.
10. Limpia tu área de trabajo.
    - Sigue las instrucciones de tu maestro(a).

El Baile De Las Etiquetas

TABLA PARA LA IDENTIFICACIÓN DE LOS POLVOS

Polvo	Propiedades Físicas	Prueba de Vinagre	Prueba de Yodo	Prueba de Repollo	Prueba de Temp.	Prueba de Solubilidad
Alka-Seltzer	trozos de tamaño irregular	burbujas	burbujas anaranjadas/marromes	permanece morado, burbujas	permanece a la misma temp.	si, burbujas
talco de bebé	polvo, quizás olor	no burbujas	anaranjado /marrón	permanece morado	permanece a la misma temp.	no
polvo para hornear	polvo fino	burbujas	burbujas negras	burbujas azules	más frío	un poco
bicarbonato de sodio	polvo fino	burbujas	anaranjado /marrón	azul	más frío	un poco
crema tártara	polvo fino	no burbujas	anaranjado /marrón	rojo	permanece a la misma temp.	un poco
detergente	trozos de tamaño irregular	burbujas	anaranjado /marrón, se disipa	verde	más caliente	un poco
sal Epsom	cristales pequeños con lados filosos	no burbujas	anaranjado /marrón	permanece morado	más frío	sí
leche en polvo	polvo fino	no burbujas	anaranjado /marrón, se disipa	permanece morado	permanece a la misma temp.	lechoso
yeso	polvo fino	burbujas	anaranjado /marrón	permanece morado	más caliente	pastoso
sal	cristales pequeños con lados filosos	no burbujas	anaranjado /marrón	permanece morado	permanece a la misma temp.	sí
almidón	polvo fino	no burbujas	negro	permanece morado	permanece a la misma temp.	pastoso
azúcar	cristales pequeños con lados filosos	no burbujas	anaranjado /marrón	permanece morado	permanece a la misma temp.	sí

El Baile de las Etiquetas

PROCEDIMIENTO CIENTÍFICO

A continuación encontrarás seis pruebas. Puedes realizar cualquier prueba, con cualquier polvo en cualquier orden. Tu objetivo es recopilar suficiente información de cada polvo para poder identificarlo.

- Ten cuidado de no mezclar los polvos entre sí en la charola para hielo, en las cucharas o en el cartón de huevos.
- Escribe tus observaciones en la tabla de datos.
- Asegúrate de limpiar el vaso plástico y el cartón de huevos entre prueba y prueba.
    - En cada caso, primero vierte los químicos de tu prueba en la basura.
    - Luego agrega un poquito de agua y limpia el recipiente con una toalla de papel.
    - Descarta la toalla de papel en la basura.

Propiedades Físicas

¿Cómo se ve el polvo?
¿A qué huele?
¿Son cristales o pedazos pequeños e irregulares?
¿Es un polvo fino o grueso?

Prueba de Vinagre

Coloca un poco de polvo(como del tamaño de un chícharo) en una de las hendiduras del cartón de huevos.
Agrega ¼ de cucharada de vinagre.
Revuelve con un palillo de dientes.
¿Qué sucede?

Prueba de Jugo de Repollo

Coloca un poco de polvo (como del tamaño de un chícharo) en una de las hendiduras del cartón de huevos.
Agrega ¼ de cucharada de jugo de repollo.
Revuelve con un palillo de dientes.
¿Qué sucede?

Prueba de Yodo

Coloca un poquito de polvo (como del tamaño de un chícharo) en una de las hendiduras del cartón de huevos.
Agrega ¼ de cucharada de solución de yodo.
Revuelve con un palillo de dientes.
¿Qué sucede?

Prueba de Temperatura

Agrega una cucharada de agua al vaso de plástico.
Toca el vaso de plástico.
Agrega una cucharada del polvo al vaso.
Revuelve con un palillo de dientes.
Toca el vaso ahora. ¿Cambió la temperatura?

Prueba de Solubilidad

Agrega una cucharada de agua al vaso de plástico.
Agrega ½ cucharada del polvo al agua.
Revuelve con un palillo de dientes .
¿Se disuelve el polvo en el agua?

El Baile de las Etiquetas

TABLA DE DATOS

Polvo (Escribe tu predicción debajo del número)	Propiedades Físicas	Prueba de Vinagre	Prueba de Yodo	Prueba de Jugo de Repollo	Prueba de Temperatura	Prueba de Solubilidad
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Concepts

By analyzing evidence left at crime scenes, scientists and detectives can solve crimes.

Words to know

atom - a very, very small particle that makes up all matter.

cast - formed from filling a mold; a copy of the item which created the mold.

chemical reaction - when two substances combine to create a new substance; often characterized by fizzing, color change, change in temperature, or creation of light.

chromatography - a process used to separate and analyze mixtures.

DNA - DeoxyriboNucleic Acid; this complex molecule carries the instructions for living things.

DNA profile - the unique pattern formed from analyzing a person's DNA.

electron - a tiny, negatively charged particle found in atoms.

fingerprint - the unique, permanent pattern of ridges and valleys on the underside of our fingers.

forensic scientist - a person who uses science to solve crimes.

graphite - a form of carbon used in pencils and fingerprint powder.

latent - hidden.

luminola - chemical which glows when it detects oxygen and iron present in blood.

mold - the impression a solid object leaves behind in soft material.

molecule - a group of at least two atoms held together in a definite arrangement.

In the puzzle below, find and circle all the "words to know."

Then use the leftover letters to discover the hidden message.

HIDDEN MESSAGE:

___ ___ ___   ___ ___ ___

___ ___ ___

___ ___ ___ ___ ___ ___ ___ ___ ___

___ ___   ___ ___ ___ ___ ___

___ ___ ___ ___ ___ ___.

Y	F	N	O	U	C	C	A	D	N
U	O	O	A	S	H	E	C	N	E
N	R	I	H	T	R	T	S	A	C
O	E	T	E	E	O	M	I	P	N
R	N	C	F	T	M	M	S	R	E
T	S	A	I	I	A	T	R	O	D
C	I	E	N	H	T	Y	T	F	I
E	C	R	G	P	O	O	S	I	V
L	S	L	E	A	G	O	L	L	E
E	C	A	R	R	R	V	E	E	E
T	I	C	P	G	A	C	R	A	C
N	E	I	R	I	P	M	N	M	A
E	N	M	I	E	H	D	O	S	R
T	T	E	N	O	Y	L	M	S	T
A	I	H	T	I	D	O	M	S	I
L	S	C	L	O	N	I	M	U	L
A	T	M	O	L	E	C	U	L	E

OMSI

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CheM LaB

Take-Home Activities

Crime Scene Chemistry

Latent Prints

Find hidden clues!

Materials:

4 or 5 pieces of mechanical pencil lead
sealing plastic bag
large marker
fluffy paintbrush
fingerprints

To do and notice:

1. Place the pencil lead in the bag and seal the bag. Roll the marker over the bag to crush the pencil lead. Continue until the lead becomes a powder.
2. Find a smooth surface, like a window, mirror, or tile counter. Press your finger onto the surface.
   - **Can you see your print?**
3. Open the bag carefully. Dip the paint-brush into the powder. Carefully brush the powder where you left your print.
   - **Can you see your print now?**

4. Find places where you think people have left finger-prints. Use your powder to reveal their prints.

A closer look:

Fingerprints are the unique, permanent pattern of ridges and valleys on the underside of our fingers.
Because fingerprints can uniquely identify people, forensic scientists and police officers use fingerprints to understand who was present at a crime scene.

Your fingers produce a special mixture of amino acids, oil, and sweat that sticks to surfaces. Fingerprint powder sticks to this mixture and reveals your fingerprint.

The fingerprint powder you made is graphite, a form of carbon. (Even though we call it "pencil lead," it does not contain lead at all.) Graphite is an ingredient in professional fingerprint powders as well.

Invisible Ink

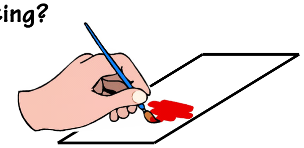
Create your own secret message!

Materials:

lemon juice
one piece of paper
one small brush or cotton swab
an oven (**CAUTION:** This experiment involves a hot oven; adult supervision is required.)

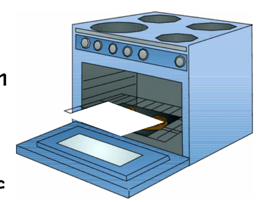
To do and notice:

1. Dip the brush or swab into the lemon juice, and use it to write on the piece of paper. Allow the paper to dry completely (about 15 minutes).
   - **Can you see the writing?**



CAUTION: The following steps involve a hot oven; adult supervision is required.

2. Warm the oven to 350°F.
3. Carefully place the paper on a rack in the oven. Close the oven and cook the paper for 10 minutes.



4. Carefully take the paper out of the oven. Turn off the oven.
   - **Can you see the writing now?**
   - **What does it look like?**

A closer look:

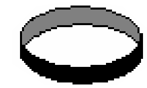
At 350°F, the oven is hot enough to burn the chemicals in the lemon juice, but it is not hot enough to burn the chemi-cals in the paper. At it burns, the lemon juice combines with oxygen in the air. This causes a brown, scorched appearance on the paper. If the oven were hotter, the paper would also combine with oxygen and burn.

Plaster Casts

Make a plaster replica

Materials:

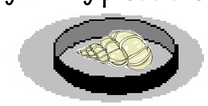
item to cast: finger, shoe, shell, small toy
oil based modeling clay
cereal box cut into two 2-inch wide strips
2 paperclips
paper cup
2 tablespoons Plaster of Paris
1 tablespoon water
tablespoon
fork



cereal box paper ring

To do and notice:

1. Use the paper clips and the cereal box strips to make a ring as shown above. This ring must be bigger than the item you want to cast.
2. Roll out the modeling clay to about 1/2 inch thick. Set the paper ring into the clay. Firmly press the item you want to cast into the clay. Carefully remove the item from the clay.
   - **Do you see the mold of your item?**

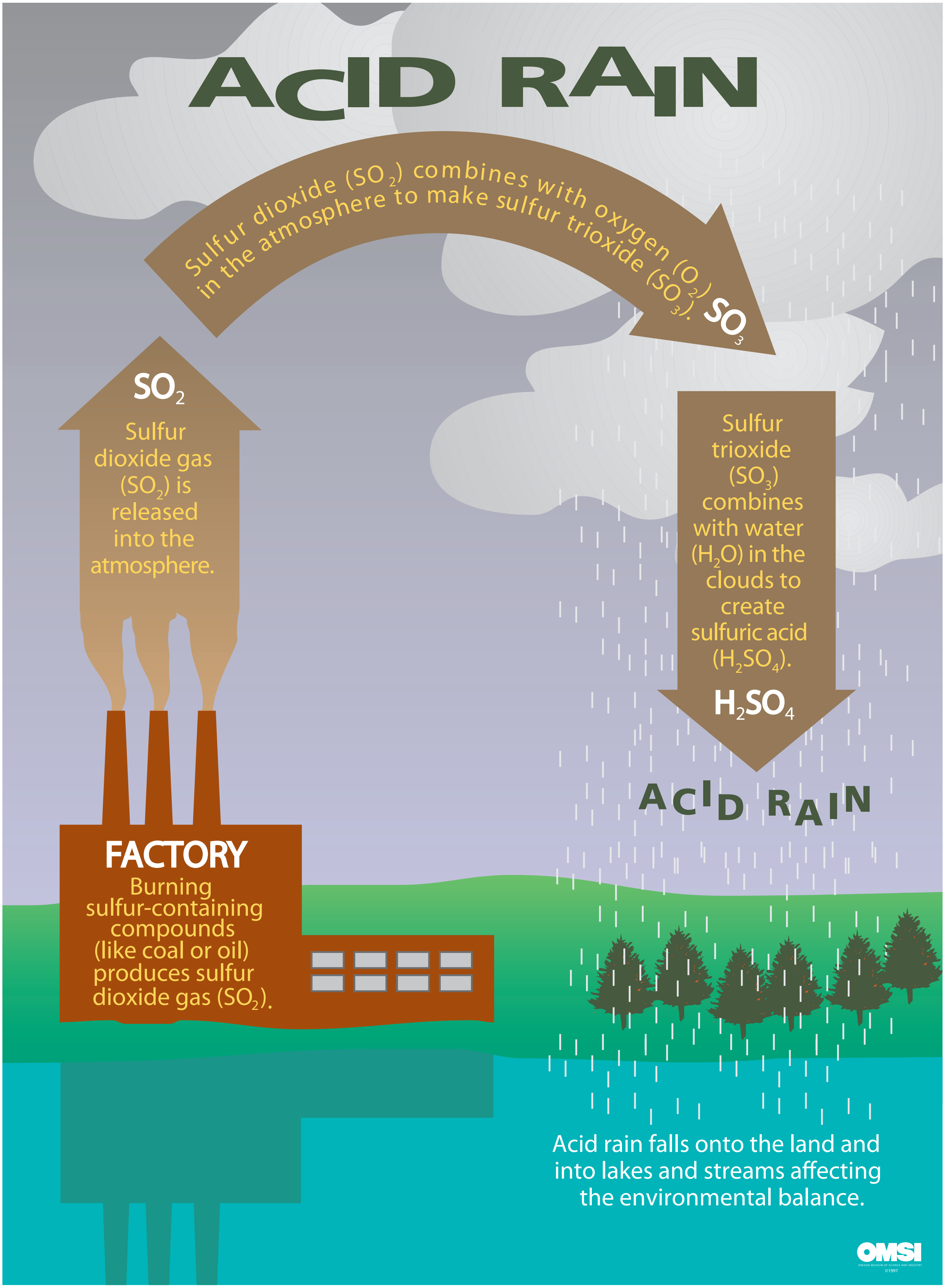


3. In the paper cup, add the Plaster of Paris and the water. Mix with the fork to make sure there are no lumps. Carefully fill your mold with the plaster. Leave the plaster to dry for a few hours or over-night. DO NOT pour extra plaster down the sink.
4. When the plaster is completely dry, carefully remove the clay. You have made a plaster cast.
   - **Does your cast look like the original item?**

A closer look:

Plaster of Paris is made from calcium sulfate ($CaSO_4$). As it combines with water, it makes a paste which solidifies.

Scientists and detectives can use plaster casts to preserve animal tracks, tire tracks, or footprints left in soft dirt or mud. The cast is a copy of whatever left the imprint.



ACID RAIN
Sulfur dioxide (SO_2) combines with oxygen (O_2) in the atmosphere to make sulfur trioxide (SO_3).
SO_3
SO_2
Sulfur dioxide gas (SO_2) is released into the atmosphere.
Sulfur trioxide (SO_3) combines with water (H_2O) in the clouds to create sulfuric acid (H_2SO_4).
H_2SO_4
ACID RAIN
FACTORY
Burning sulfur-containing compounds (like coal or oil) produces sulfur dioxide gas (SO_2).
Acid rain falls onto the land and into lakes and streams affecting the environmental balance.
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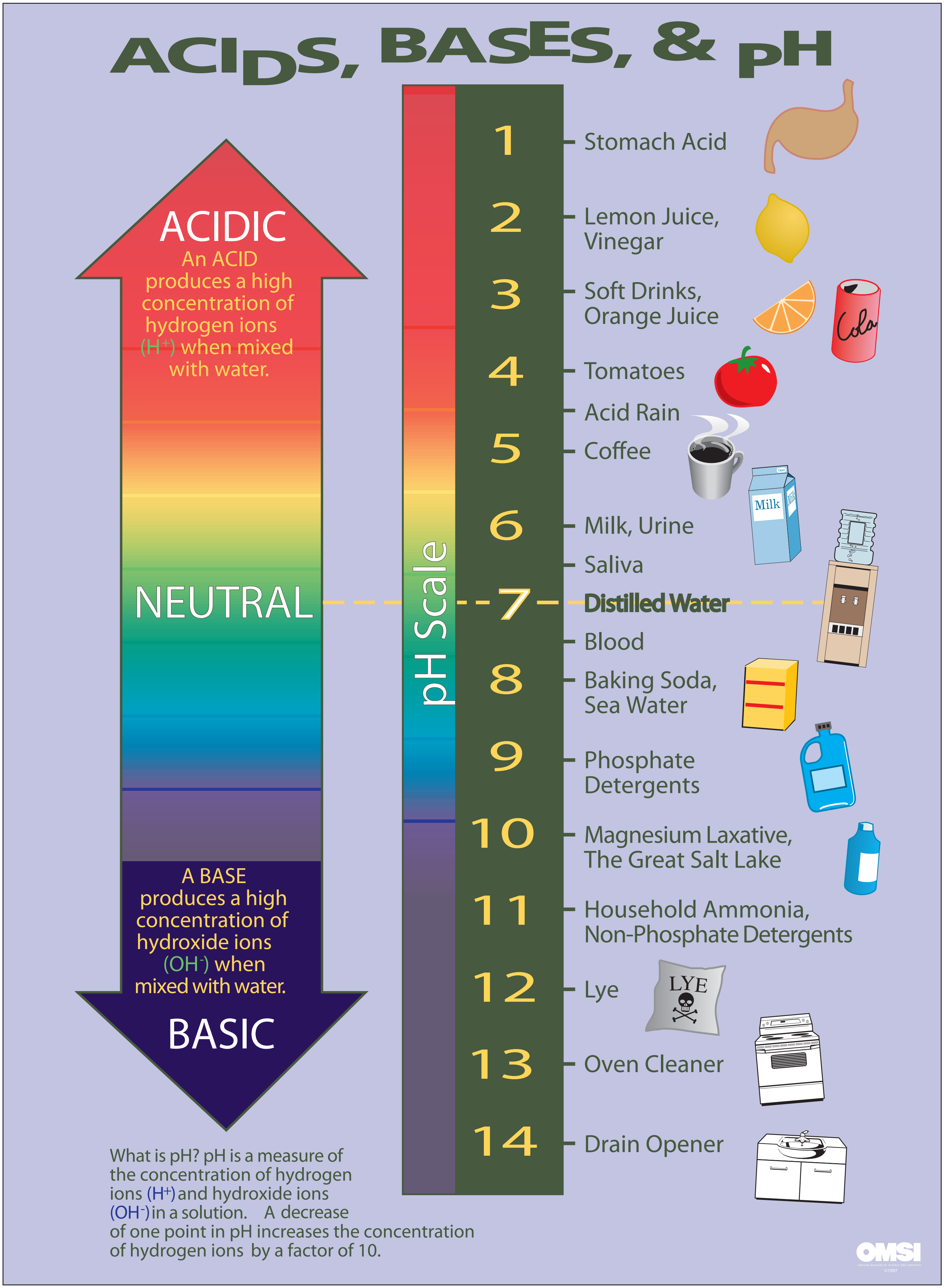
ACIDS, BASES, & pH
ACIDIC
An ACID produces a high concentration of hydrogen ions (H^+) when mixed with water.
NEUTRAL
A BASE produces a high concentration of hydroxide ions (OH^-) when mixed with water.
BASIC
pH Scale
1 Stomach Acid
2 Lemon Juice, Vinegar
3 Soft Drinks, Orange Juice
Cola
4 Tomatoes
Acid Rain
5 Coffee
Milk
6 Milk, Urine
Saliva
7 Distilled Water
Blood
8 Baking Soda, Sea Water
9 Phosphate Detergents
10 Magnesium Laxative, The Great Salt Lake
11 Household Ammonia, Non-Phosphate Detergents
12 Lye
LYE
13 Oven Cleaner
14 Drain Opener
What is pH? pH is a measure of the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in a solution. A decrease of one point in pH increases the concentration of hydrogen ions by a factor of 10.
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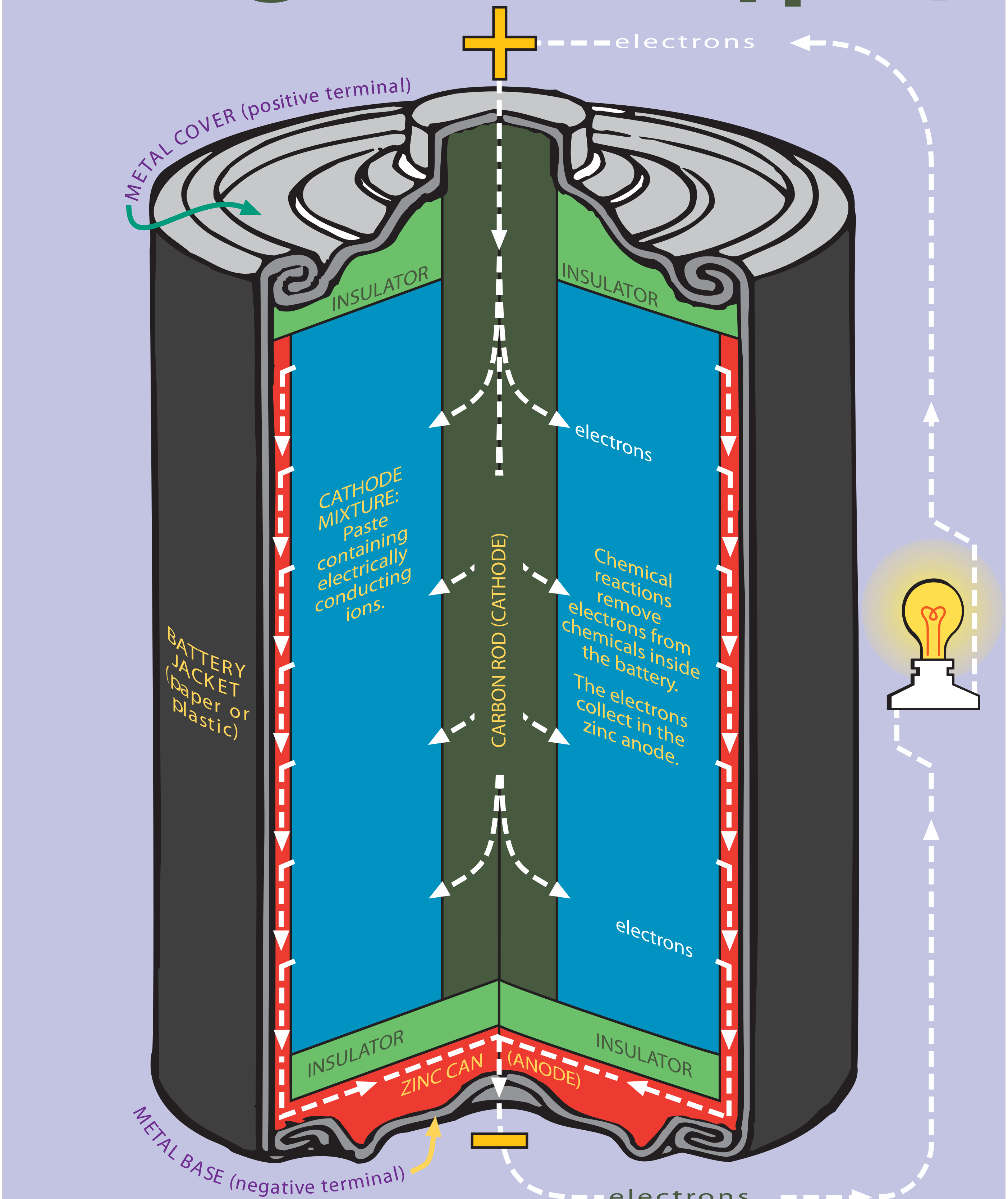
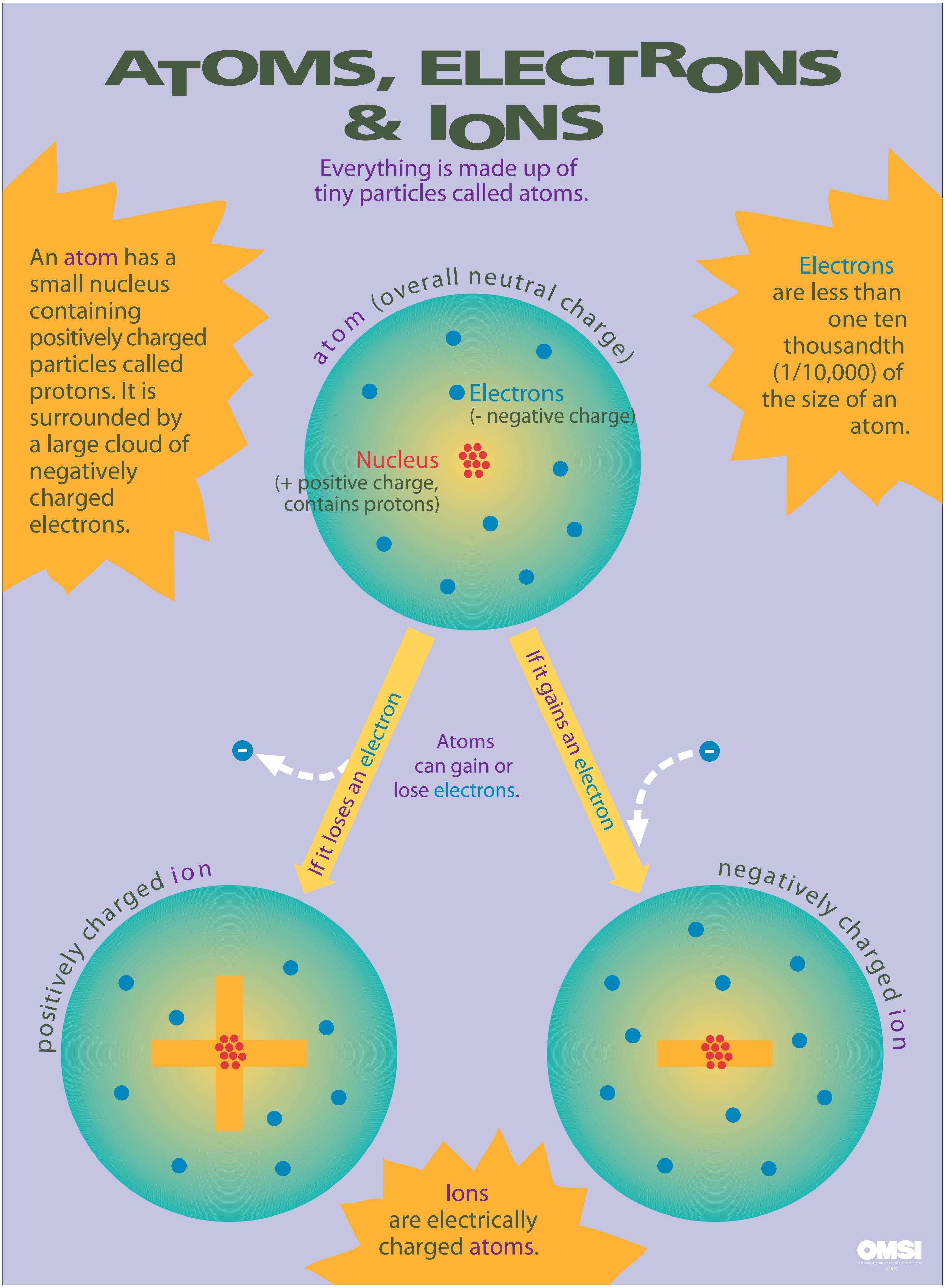
ANATOMY OF A BATTERY



When a wire connects the negative and positive terminals of the battery, the electrons flow through the wires from the anode to the cathode.


ATOMS, ELECTRONS & IONS
Everything is made up of tiny particles called atoms.
An atom has a small nucleus containing positively charged particles called protons. It is surrounded by a large cloud of negatively charged electrons.
Electrons are less than one ten thousandth (1/10,000) of the size of an atom.
atom (overall neutral charge)
Electrons
(- negative charge)
Nucleus
(+ positive charge, contains protons)
If it loses an electron
If it gains an electron
Atoms can gain or lose electrons.
positively charged ion
negatively charged ion
Ions are electrically charged atoms.
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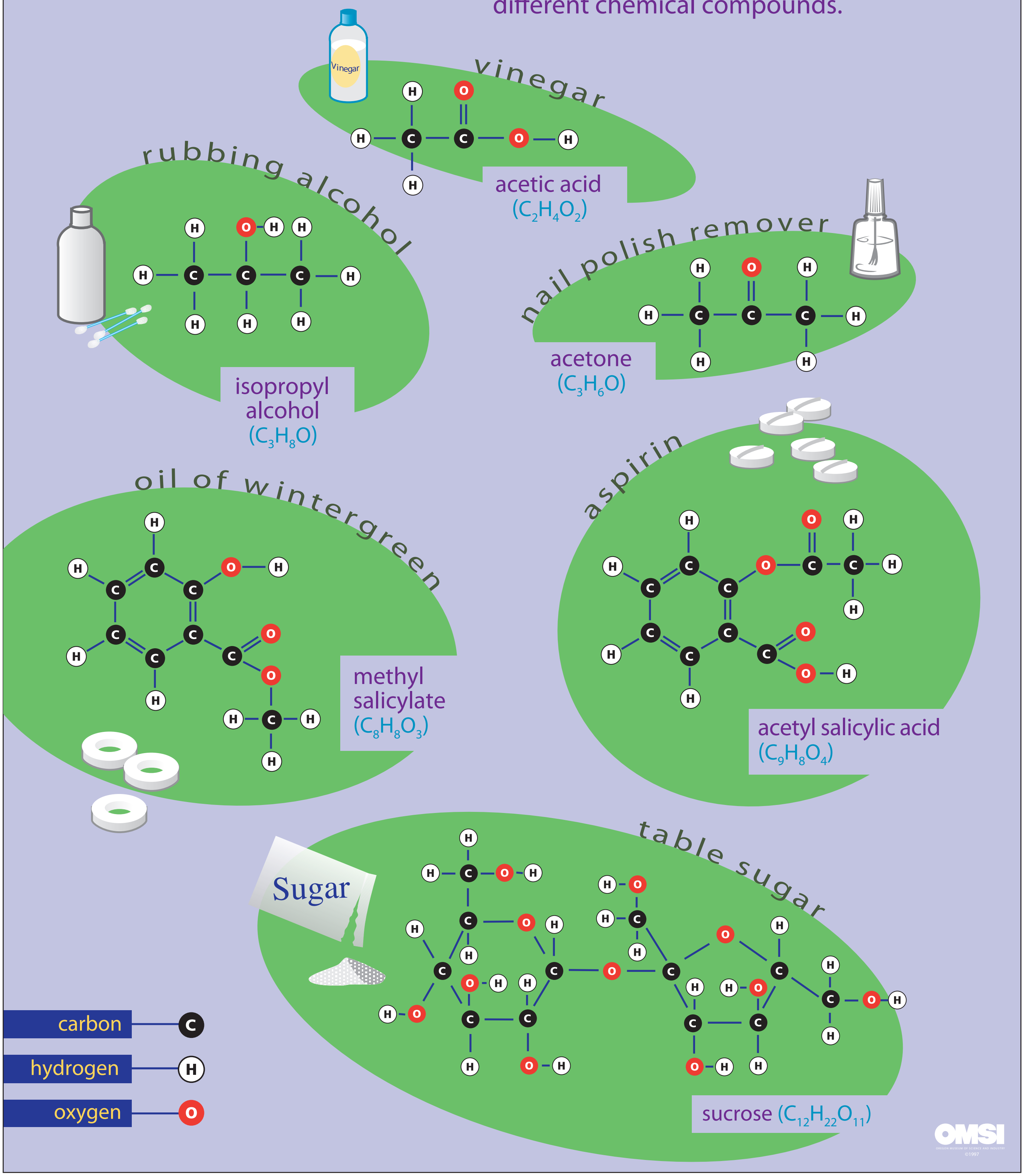
CARBON, HYDROGEN, & OXYGEN

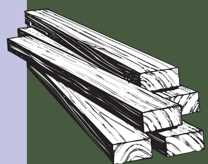
Different combinations of the common elements carbon(C), hydrogen(H), and oxygen(O) can make many different chemical compounds.

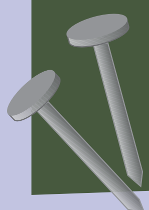
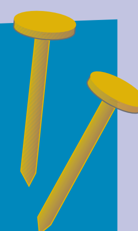
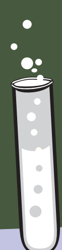
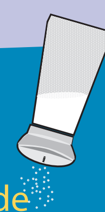


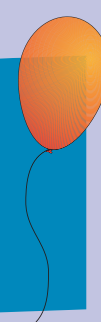
CHEMICAL REACTIONS

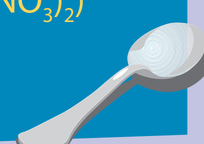
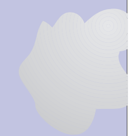
During a chemical reaction, the original materials (the reactants) are changed into other types of materials (the products).

REACTANTS	TYPE OF REACTION	PRODUCTS
wood & oxygen	COMBUSTION — combine by burning to form	smoke, ash, water, heat
iron(Fe) & oxygen(O_2)	OXIDATION — combine to form	rust (iron oxide) (Fe_2O_3)
hydrochloric acid (HCl) & sodium hydroxide (NaOH)	ACID/BASE — neutralize each other to form	water(H_2O) & sodium chloride (NaCl, salt)
water (H_2O)	DECOMPOSITION — breaks down to form	hydrogen gas(H_2) & oxygen gas(O_2)
silver nitrate($AgNO_3$) & copper(Cu)	REPLACEMENT — trade atoms to form	copper nitrate($Cu(NO_3)_2$) & silver(Ag)





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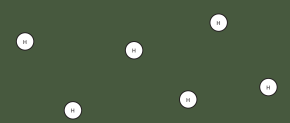
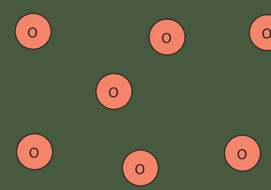
TYPES OF MATTER

ELEMENT

Hydrogen (H) Atoms



Oxygen (O) Atoms



Elements are made up of very very small particles called atoms.

SOME OTHER ELEMENTS:

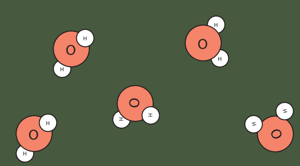
Copper (Cu)

Neon (Ne)

Gold (Au)

COMPOUND

Water (H_2O) molecules are made from 2 hydrogen (H) atoms and 1 oxygen (O) atom.

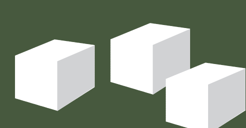


Compounds are made up of molecules.

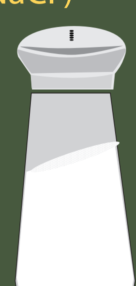
Molecules are made of two or more atoms that are chemically bonded together.

SOME OTHER COMPOUNDS:

Sugar ($C_{12}H_{22}O_{11}$)

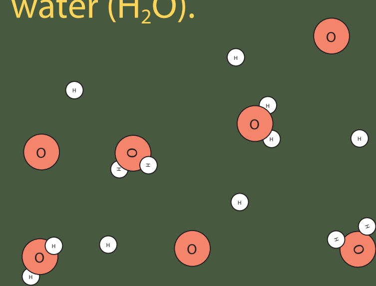


Salt (NaCl)



MIXTURE

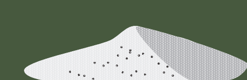
A mixture of hydrogen (H) and oxygen (O) and water (H_2O).



Mixtures are made up of particles (atoms and/or molecules) that are mixed together but are not chemically bonded to each other.

SOME OTHER MIXTURES:

Salt and pepper



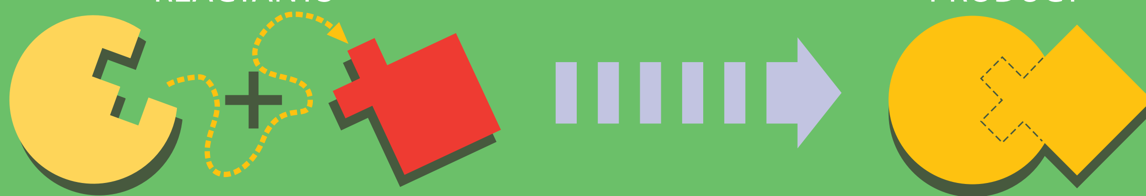
Carbon dioxide gas and soda

ENZYMES

Enzymes are reusable proteins that speed up (catalyze) biochemical reactions.

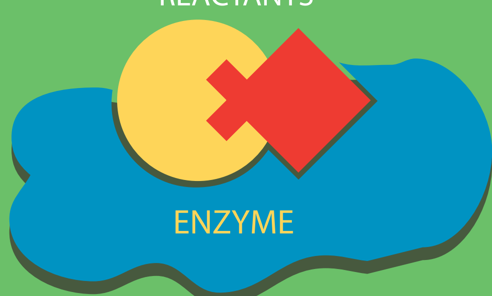
Without an Enzyme: SLOW Reaction

Molecules meet by chance and need energy to combine.

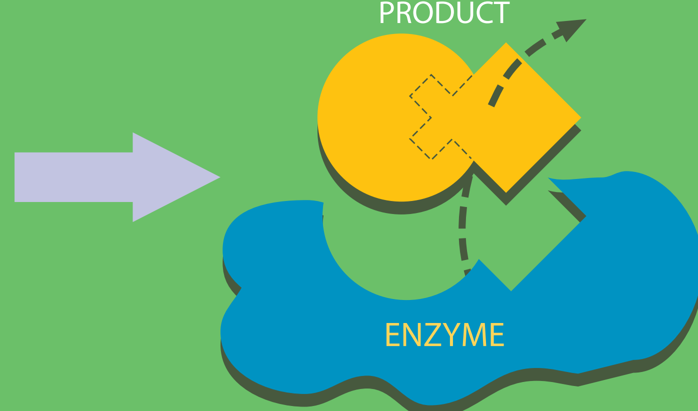


With an Enzyme: FAST Reaction

An enzyme holds the molecules in the proper position and reduces the amount of energy they need to combine.



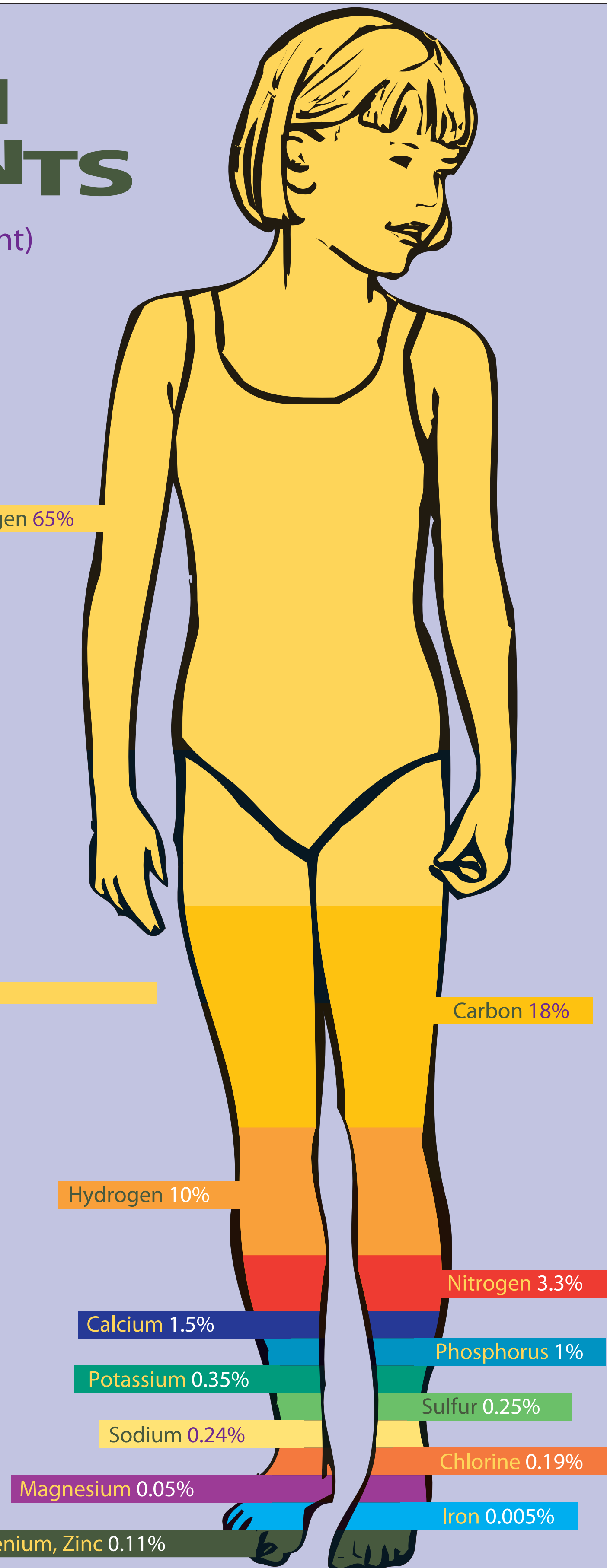
1. Reactant molecules fit into enzyme like a key in a lock, enabling a reaction to occur quickly.

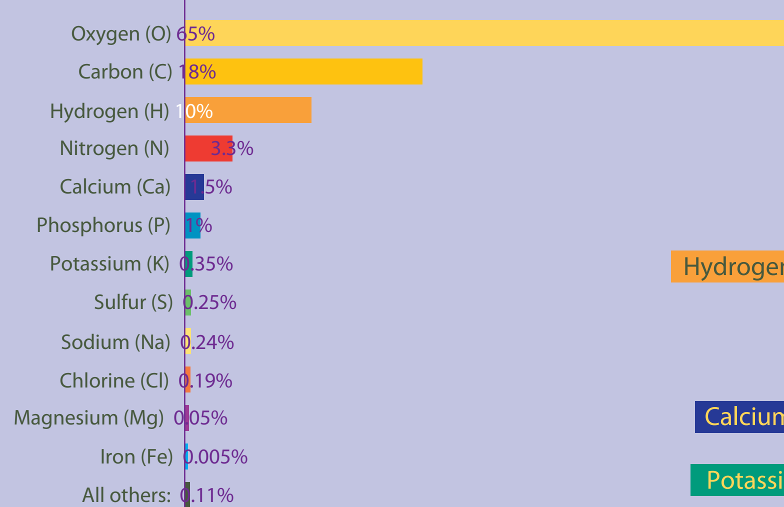


2. The enzyme can now be reused in a new reaction.

HUMAN ELEMENTS

The percentage (by weight) of chemical elements in the human body





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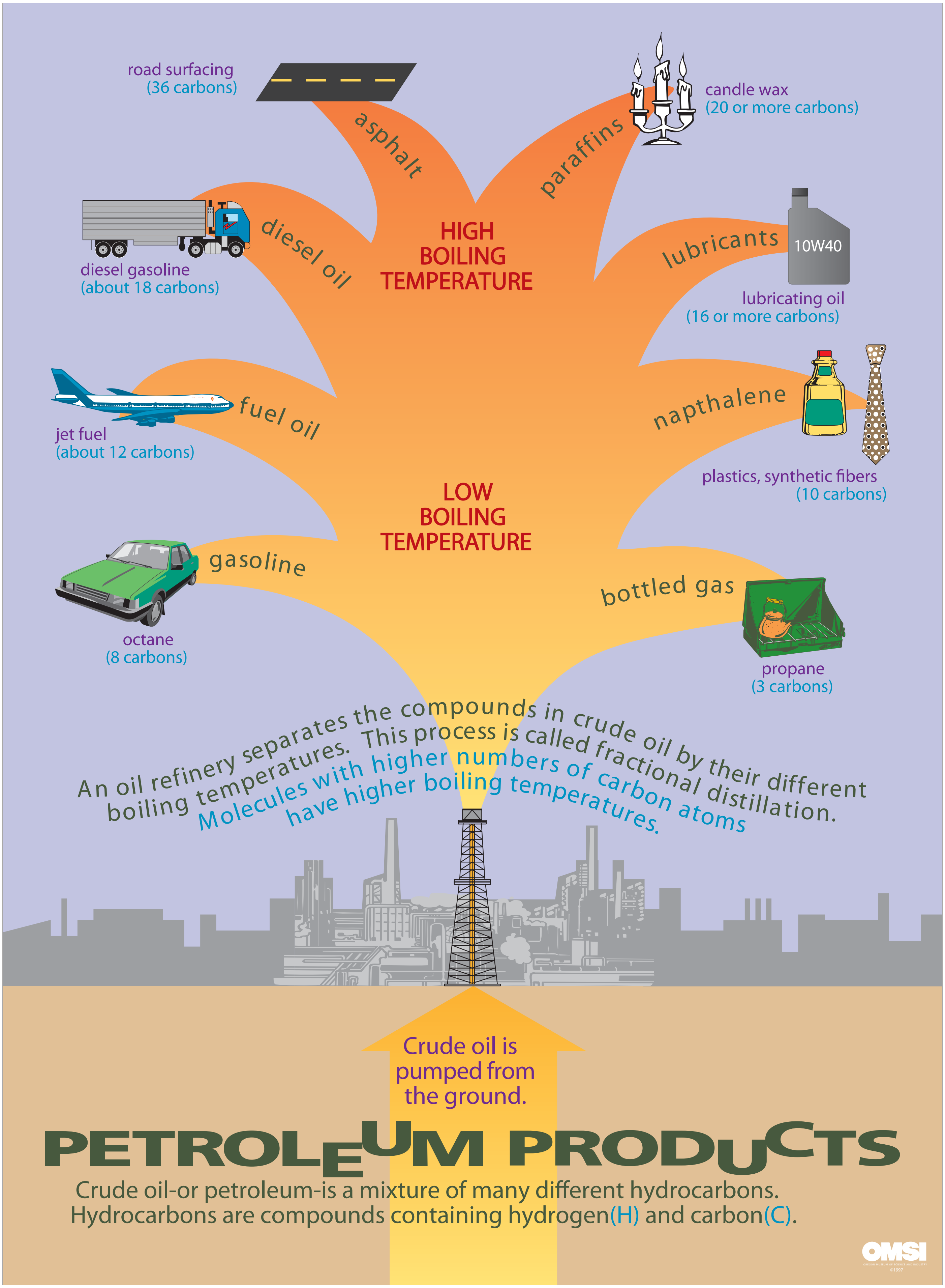
road surfacing
(36 carbons)
asphalt
paraffins
candle wax
(20 or more carbons)
diesel oil
diesel gasoline
(about 18 carbons)
HIGH BOILING TEMPERATURE
lubricants
10W40
lubricating oil
(16 or more carbons)
fuel oil
jet fuel
(about 12 carbons)
napthalene
plastics, synthetic fibers
(10 carbons)
LOW BOILING TEMPERATURE
gasoline
octane
(8 carbons)
bottled gas
propane
(3 carbons)
An oil refinery separates the compounds in crude oil by their different boiling temperatures. This process is called fractional distillation.
Molecules with higher numbers of carbon atoms have higher boiling temperatures.
Crude oil is pumped from the ground.
PETROLEUM PRODUCTS
Crude oil-or petroleum-is a mixture of many different hydrocarbons.
Hydrocarbons are compounds containing hydrogen(H) and carbon(C).
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PLASTICS
Reactions between simple chemicals form many types of complex plastics.
Plastics can be molded to form many familiar items.
carbon
hydrogen
oxygen
chlorine
PLASTIC
polyvinyl chloride (PVC)
MADE FROM
vinyl chloride
rain coats
USED TO MAKE
pipes
acrylic
PLASTIC
acrylic acid
MADE FROM
clothing
USED TO MAKE
HOUSE & TRIM FLAT FINISH
acrylic paint
PLASTIC
nylon
MADE FROM
adipic acid
rope
USED TO MAKE
carpet fibers
polyethylene
PLASTIC
ethylene
MADE FROM
bottles
USED TO MAKE
film
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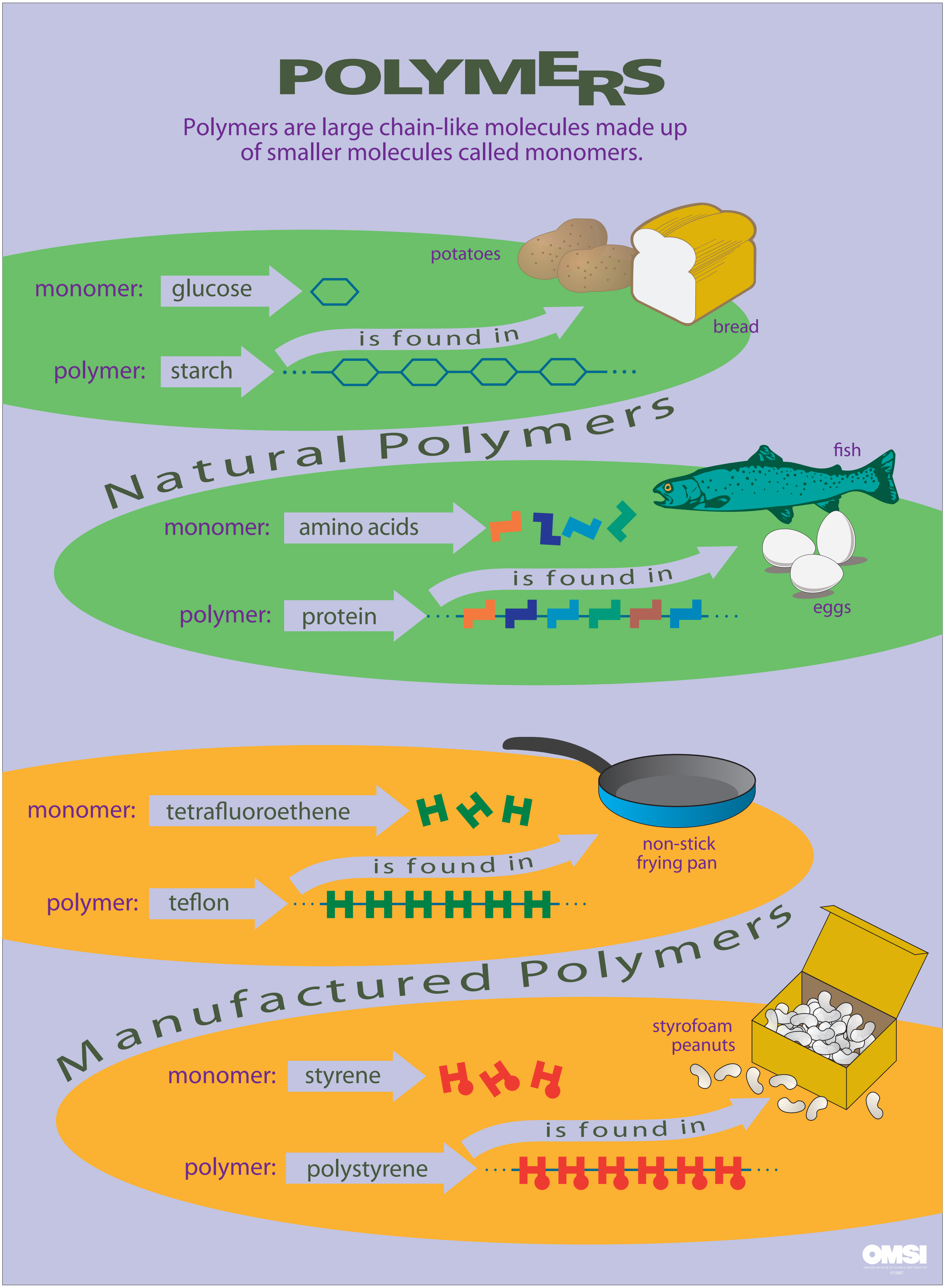
POLYMERS
Polymers are large chain-like molecules made up of smaller molecules called monomers.
potatoes
bread
monomer: glucose
is found in
polymer: starch
Natural Polymers
fish
monomer: amino acids
is found in
polymer: protein
eggs
monomer: tetrafluoroethene
non-stick frying pan
is found in
polymer: teflon
Manufactured Polymers
styrofoam peanuts
monomer: styrene
is found in
polymer: polystyrene
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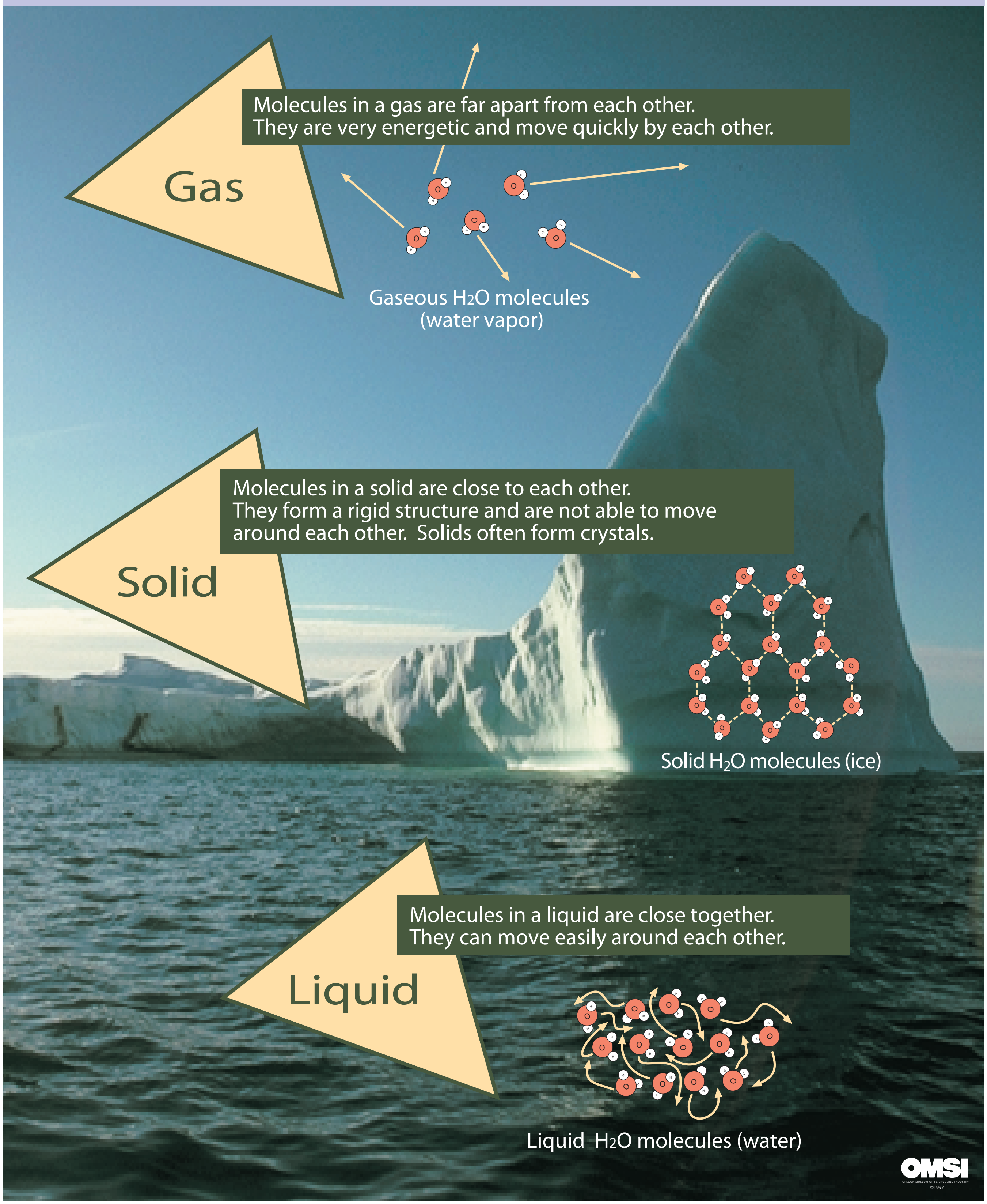
Three Physical States of Matter



Glossary

acid: a substance with an excess of available hydrogen ions; often sour in taste

acid rain: cloud or rain droplets containing pollutants (e.g., sulfuric acid, nitric acid) that make them acidic

albumin: protein found in egg whites

anthocyanin: a class of chemicals found in plants; these chemicals are often responsible for color changes

aquifer: sediment or rock in which water is stored and can flow through

atom: a very, very small particle that makes up all matter

azo dye: class of food and clothing dyes that contains a nitrogen-nitrogen double bond

bacteria: very small organisms each made of just one cell

base: a chemical or compound that takes up hydrogen ions; often bitter in taste

battery: a combination of metals and other chemicals that react together to produce electricity, i.e., moving electrons

biochemistry: the study of chemical reactions that occur within living things

biochemists: scientists who study the chemistry of life processes

biodegradable foam: a form of packaging material made of starch that has been filled with many bubbles of air; primarily used for protecting materials during shipping

biodegrade: to break down by natural processes

bromelain: enzyme from pineapples that cuts up proteins

capillary action: the tendency of small tubes to draw liquid up into them, against the force of gravity, due to the attraction of water to the molecules in the sides of the tubes

carbonate: an ion made of one carbon atom and three oxygen atoms; CO_3^{2-}

casein: protein found in cow milk

cell membrane: a thin barrier that surrounds the contents of plant and animal cells; provides structure and organization to the cell and controls the passage of water and other chemicals both into and out of the cell.

cell wall: the rigid outermost barrier that surrounds the cell membrane; found in all plants and some algae, bacteria, and fungi; absent from all animal cells

charged molecules: molecules that have small positive and small negative charges

chemical bond: a connection that holds two atoms together

chemical change: when substances change their properties and their molecules change; examples include burning, rusting, forming a new material, creating gas bubbles, creating light

chemical reaction: when two or more substances combine to make a new substance; often characterized by foaming, heating, cooling, color changing

chemoreception: the way the sense of smell works; the body's response to a chemical stimulus

chromatogram: a paper showing a mixture separated using chromatography

chromatography: a process scientists use to separate, analyze, or purify mixtures

concentration: the ratio of the amount of a chemical in a solution to the volume of the solution

conductor: a material that transfers heat or electricity easily

constant: a quantity, value, or condition in an experiment that is fixed, or unchanged; see also **control**

control: to keep a quantity, value, or condition the same in an experiment

corrode: to slowly weaken or decay, often due to chemical reactions

corrosive: causing visible destruction of human skin tissue; able to damage metals or minerals

covalent bonds: connections between atoms where the electrons are equally shared; molecules with these bonds tend to be balanced electrically

crystal: a chemical in solid form with the molecules in special arrangements; usually refers to pure solids with shiny facets and faces, such as diamonds

curcumin: the active ingredient in turmeric that changes color

curds: the solid part of milk

current: a flow of electrons

demographer: a scientist who studies the characteristics of human populations, such as size, growth, density, distribution, and vital statistics

denature: to cause a protein to change its shape; when a protein changes its shape, it loses its properties

dense: describes how tightly packed molecules are in a substance

density: describes how tightly packed matter (molecules, people) is in a space; dense is the adjective, density is the noun; mathematically defined as a ratio of the mass of an object to the volume of the object

dependent variable: the resulting change in an experiment; the variable that is measured

diffuse: to spread out and disperse

diploid: having two copies of genetic material

dissolve: when the molecules of a substance separate and become completely surrounded by the molecules of another substance

DNA profile: a chromatogram of an individual's DNA, used to identify individuals or to diagnose disease

DNA: Deoxyribo**N**ucleic **A**cid; a long molecule found in the nucleus of a cell and shaped like a double helix; carries genetic information for living things

DNase: an enzyme that breaks down DNA; "-ase" stands for enzyme

dots per inch (dpi): a measure of digital picture resolution; the number of dots that fit in a line one inch long

ductile: can be stretched or bent without breaking

electricity: created by a continuous flow of electrons through a wire

electron: negatively charged particle found in atoms

emulsifier: something added to two liquids that normally won't dissolve to keep them uniformly mixed

emulsion: a suspension of tiny droplets of one liquid in another liquid; the two liquids normally do not dissolve in one another

endothermic: a process that requires heat or that may feel cold; "endo-" means "into"

energy: the ability to do work; anything that is not matter

enzyme: complex protein produced by cells; acts to speed up a specific biochemical reaction

evaporation: the gradual transition of a liquid or solid into a gas

exothermic: a process that releases energy, causing it to feel warm; "exo-" means "out of"

filter: a device, usually containing sand, charcoal, dirt, or some other porous material, that traps the contaminants in water when water passes through

fingerprint: unique, permanent pattern of ridges and valleys on the underside of a finger

forensic scientist: scientist who studies evidence left at a crime scene

gas chromatography: process that uses heated gas to carry and separate a mixture into its component parts

gas: a state of matter in which molecules are spread far apart and interact only by random collisions; this state will expand to fill a container of any size

gel electrophoresis: process that uses gel and electricity to separate a mixture into its component parts; used primarily for DNA, proteins, or other biological molecules

graphite: a form of carbon used in pencils

groundwater: water that is held underground

hydrogen ion: a hydrogen atom that is missing one electron; often produced by acids and taken up by bases

hydrophilic: attracted to water; easily absorbs water and dissolves in water

hydrophobic: repelled by water; unable to absorb water or dissolve in water

hypertonic: having a higher concentration of particles in solution; "hyper-" means "more"

hypotonic: having a lower concentration of particles in solution; "hypo-" means "less"

impervious cover: material that blocks water from getting to the ground; e.g., pavement, buildings, roads, sidewalks

independent variable: the factor in an experiment that is altered by experimenter; the tested variable

indicator: a substance that changes color to indicate the presence or concentration of a certain chemical

insoluble: unable to dissolve

ionic bonds: connections between atoms where the electrons are transferred from one atom to another; molecules with these bonds tend to be highly charged

ions: an electrically charged atom or group of atoms

isotonic: having the same concentration of particles in solution; "iso-" means "same"

lactose: sugar found in cow milk

landfill: location designated to collect trash

latent print: a fingerprint that is present, but not visible

leach: dissolving and then removing nutrients, minerals, or pollutants from the soil by running water through the soil

leaking underground storage tank (LUST): a buried container that has broken and started to leak its contents

like dissolves like: the principle in chemistry where substances with similar molecules mix well

lipids: group of organic molecules that includes oils, fats, and waxes; lipids, carbohydrates, and proteins make up the main structures of cells

liquid: a state of matter in which molecules move relatively freely and fill their container

lyse: to break open or split

mass: the amount of matter in an object or substance; measured by weight

matter: anything that has mass and occupies space; stuff

membrane: a thin film that forms a barrier

metal: any material that is shiny, can be molded, stretched, or shaped and transfers heat or electricity; can be an element or mixture of elements

mixture: two or more substances that are mixed together but are not chemically bonded

molecule: a group of at least two atoms held together in a definite arrangement

neutral: a chemical that is neither acid nor base, and typically has a pH of 7

neutralize: to make chemically neutral (i.e., bring to a pH of 7); to make inert and less dangerous

non-point source pollution: pollution that accumulates from multiple sources

non-polar: describes neutral molecules whose charges are electrically balanced

nuclear membrane: similar to the cell membrane; surrounds the contents of the nucleus, separating it from the rest of the cell

nucleus: a compartment inside the cell that contains the cell's genetic information

octoploid: having eight copies of genetic material

osmoregulation: the process whereby living cells control the flow of water across their cell membranes

osmosis: the movement of water molecules across a barrier; water spontaneously moves from a region of low particle concentration to a region of high particle concentration

oxidation: the chemical process of losing electrons; always paired with a reduction process

oxidizer: a chemical that supplies oxygen to a reaction; a chemical that removes electrons from other atoms or molecules

papain: enzyme from papayas that cuts up proteins

paper chromatography: process that uses paper and liquid to separate a mixture into its component parts

permeable: allows another substance to pass through

pH: a measure of the acidity or basicity of a solution, numbered on a scale where 1–6 indicates acidic, 8–14 is basic, and 7 is neutral

physical change: when substances change their properties without any changes to their molecules; e.g., melting, freezing, boiling, creating or separating a mixture, cutting, denting, scratching

plating: covering the surface of one metal with a thin layer of another metal

plume: an area where a contaminant has spread out

point-source pollution: pollution that can be traced to a specific source

polar bonds: connections between atoms where the electrons are not equally shared; molecules with these bonds tend to have a small unbalanced electrical charge

polar molecules: molecules with partial electrical charges

pollutant: an agent that can potentially harm or contaminate a resource

polymer: a large molecule made up of many repeated molecules

polystyrene: long chains of styrene molecules; this plastic is mainly used for cups and food containers

polyvinyl acetate: the active ingredient in liquid white glue and liquid clear glue

population scientist: a scientist who studies the growth and density of populations

porous: describes the amount of open spaces between particles in a material

powder: composed of particles that are too small to be seen easily

precipitate: to come out of a liquid solution as a solid; to come out of a gas solution as a liquid

pressure: continuous force applied by touching; force on a surface created by the collisions of molecules

protein: complex molecule found throughout the body; hormones, enzymes, and antibodies are all proteins, also hair, skin, nails and muscle

reaction rate: the speed at which two chemicals react with each other

recycle: use again; break down products into their component parts and remake into the same or different product

reduction: the chemical process of gaining electrons; always paired with oxidation

reducer: a chemical that supplies electrons to other atoms or molecules

retention factor: a ratio comparing how far a chemical travels compared to how far its carrier traveled; abbreviated R_f

salting out: adding salt to a solution of water and another liquid in order to separate or purify the liquid components

silica: the main molecule in sand and quartz; SiO_2

solid: a state of matter in which atoms or molecules are closely and rigidly packed and resist changes in shape or volume

soluble: able to dissolve

solutes: dissolved particles in a liquid solution, e.g., salt is a solute in water when it is dissolved

starch: long chains of sugar molecules; plants create this molecule as a way to store energy

Styrofoam: brand name for polystyrene plastic that has been filled with many bubbles of air; primarily used for protecting materials during shipping

sublimation: the transition of a solid directly into a gas, without melting into a liquid first

surface area: the amount of accessible space for a reaction to happen

surface tension: an elastic-like force in liquids caused by the molecules at the surface being attracted to one another

temperature: a measure of the warmth of a substance, based on how fast its molecules are moving

turgid: so full of water as to be stiff and rigid

underground storage tank (UST): buried container that holds some substance; e.g., gas station tanks, septic tanks, oil tanks

urban runoff: excess water, often contaminated with pollutants, that tends to dump in streams and rivers before being filtered through the ground

variable: a changeable factor in a scientific experiment (scientists may choose to change or hold constant any particular variable)

virus: a simple, small infectious agent made from genetic material with a thin protein coat; cannot live without entering a cell so is not considered living

volume: the amount of space filled by an object or substance

Grade Level

This table lists the intended grade level for the activities in this book. The intended grade level is listed in the introductory section of each activity. All activities may be adapted to any grade level. Some activities have extensions to allow differentiation for multiple grade levels.

	Bend a Carrot	Big Things Come in Little Packages	Choose Your Ooze	Cleaning with Dirt	Color Me Blue	Density Rainbow	DNA Extraction	Dye Detective
K		Main, Ext A	Main, Ext A					Main
1								
2						Main, Ext A		
3		Ext B						
4		Ext C	Ext B		Main, Ext A, Ext B		Main, Ext A, Ext B	Ext A
5	Main, Ext A, Ext B			Main, Ext A, Ext B		Ext B, Ext C		Ext B, Ext C
6					Ext C			
7	Ext C							
8								

				Ext B				Main Ext A	Foam Peanuts
			Ext B			Main Ext A			Inner Space
						Main Ext A Ext B			Kool Colors
				Main Ext A Ext B Ext C					Latent Prints
					Main				Lost Labels
				Ext B	Ext A			Main	Matter of Degree
					Ext A Ext B			Main	Odors Aloft
						Ext C		Main Ext A Ext B	Of Cabbages and Kings
			Ext B		Main Ext A				Penny for Your Thoughts
			Main Ext A Ext B						Pollution Diffusion
					Main Ext A Ext B				Reaction: Yes or No?
		Main Ext A Ext B Ext C							Salting Out
					Main Ext A				Sticky Situation

Index

This index is up to date as of press time. To see the latest version of this document, visit **www.omsi.edu/k8chemistry**.

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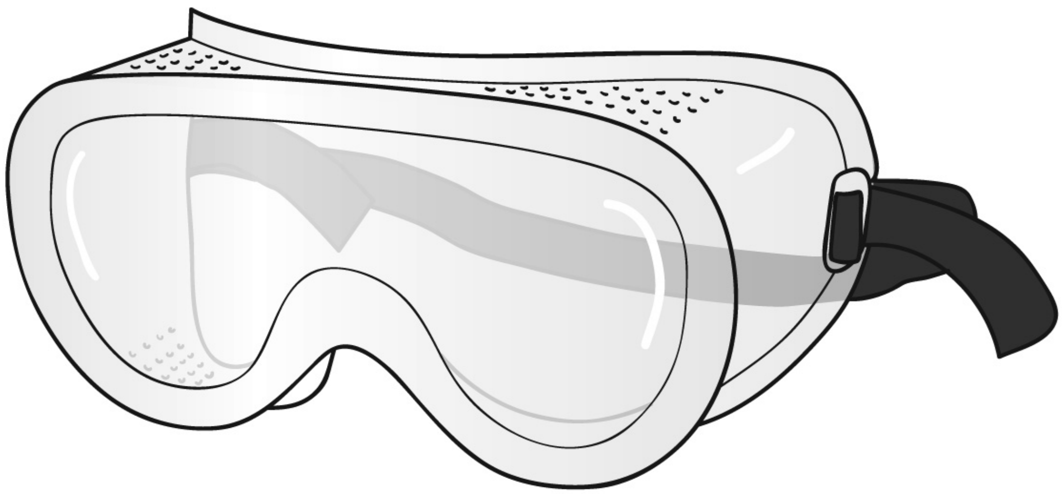


The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Periodic Table Facts

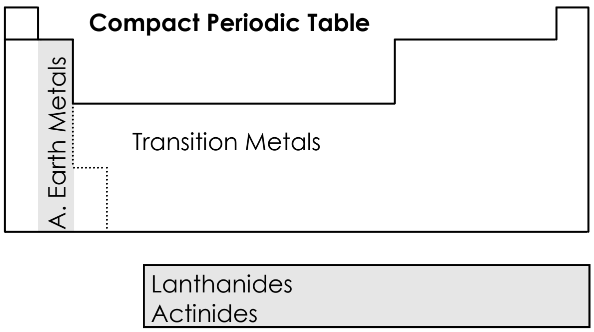
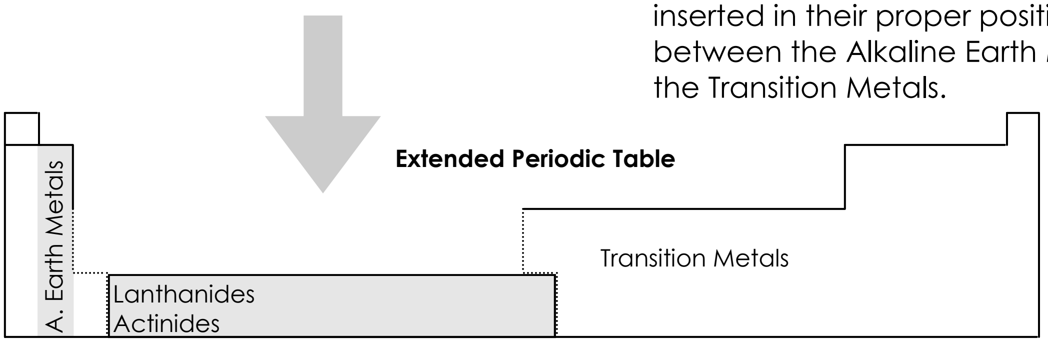


Table Layout

The periodic table is normally presented in a compressed form with the Lanthanides (elements 57-71) and Actinides (elements 89-103) in separate rows below the rest of the table. This is done to make the table more compact. In the extended table, shown below, these elements are inserted in their proper position between the Alkaline Earth Metals and the Transition Metals.



Periodic Trends

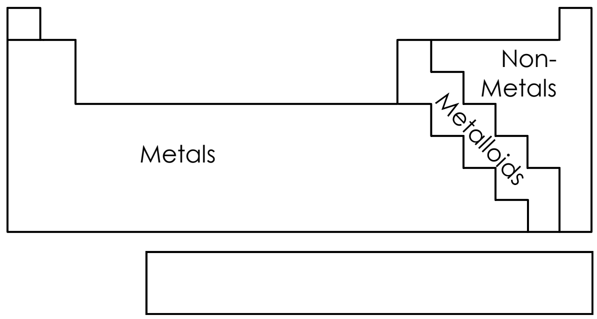
Dmitri Mendeleëv organized elements in the Periodic Table according to their mass and reactive properties. He recognized that some elements had similar properties, so he placed them in the same column. He placed the elements from left to right in order of increasing mass. Mendeleëv left spaces in his original table for elements that hadn't yet been discovered.

How Small Are Atoms?

Atoms are very, very small. To understand how small atoms are, start by looking at a meter stick. A meter can be divided into 1000 smaller lengths called *millimeters*. Now think of that millimeter and divide it into 1000 smaller lengths called *micrometers*. Now think of that micrometer and divide it into 1000 even smaller lengths called *nanometers*. One nanometer is large enough for about 5 carbon atoms.

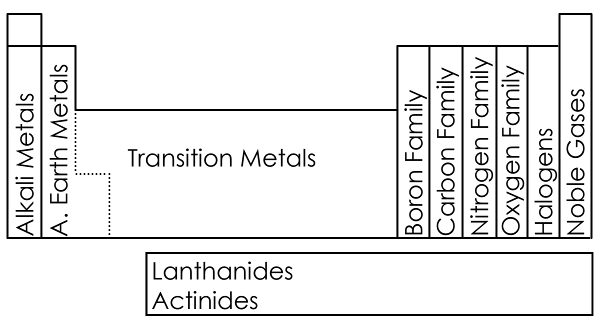
It would take 7,000,000 (7 million) carbon atoms stacked on top of each other to be the thickness of a dime.

It would take 120,000,000 (120 million) carbon atoms to cross the face of a dime.



What's a Metal?

Most of the elements in the Periodic Table are metals. This means they are shiny, can be molded, stretched or shaped, and transfer heat or electricity. Some elements are non-metals, which means they don't have these properties. Still fewer are metalloids, which means they have some metallic properties.



Periodic Families

Elements are grouped into columns, or families. All the elements in a family have similar properties. Some examples are described below:

Alkali Metals—These elements are very reactive. They especially react with water, in some cases making large explosions.

Halogens—Almost all of these elements occur naturally in pairs: F_2, Cl_2, Br_2, I_2.

Noble Gases—These elements are famous for being very stable. Since they don't often react, scientists only discovered them after the periodic table was made.

Element Names

Most names come from words describing the characteristics of the element such as its color, texture, origin, etc. Most descriptive names are from Greek and Latin words, but some are from other languages like Swedish or German. Other sources of names are people (real or mythological), places, or astronomical bodies.

The atomic symbol is always written as one or two letters with only the first letter capitalized. The names of elements are not capitalized.

carbon [C]—from Latin, *carbo*, means "charcoal"; known to the Ancient World

chlorine [Cl]—from Greek, *chloros*, means "greenish-yellow color"; discovered in 1774

helium [He]—from Greek, *helios*, means "the sun"; first detected in 1895 on the sun

hydrogen [H]—from Greek, *hydros*, means "water forming"; discovered in 1766; the first gas discovered

phosphorous [P]—from Greek, *phosphoros*, means "light bearing"; discovered in 1669; some phosphorus compounds glow in the dark

polonium [Po]—discovered by Marie Curie in 1898 and named for her native country, Poland; the rarest natural element

silver [Ag]—symbol from Latin, *argentum*; known to the Ancient World; the best conductor of heat and electricity

tungsten [W]—from Swedish *tung sten*, means "heavy stone"; symbol from German *wolfram* means "wolf's froth"; metal with the highest melting point

Activity Links to Posters

The full-color posters provided at the end of this book are useful for both introducing and reinforcing concepts. They are also on the Supplemental CD for you to print on an overhead transparency or project from a computer. Full size (22in. x 28in.) posters are also available from the OMSI Science Store.

	Bend a Carrot	Big Things Come in Little Packages	Choose Your Ooze	Cleaning with Dirt	Color Me Blue	Density Rainbow
Acid Rain: shows how pollution from sulfur containing compounds reacts with the atmosphere to create acid rain.				■		
Acids, Bases, and pH: complete scale gives examples of common items at each pH.						
Anatomy of a Battery: shows how electricity is created when the electrons flow from anode to cathode in a battery.						
Atoms, Electrons, & Ions: diagrams and facts about atoms, electrons, and ions.	■	■				■
Carbon, Hydrogen, and Oxygen: molecular diagrams of common organic molecules.						■
Chemical Reactions: names, definitions, and examples of different reactions.			■		■	
Enzymes: diagram showing how enzymes assist reactions.						
Human Elements: shows the percent (by mass) of chemical elements in the human body.	■					
Petroleum Products: examples of all the products that are made from refining petroleum.			■	■		
Plastics: molecular diagrams and examples of common plastics.			■			
Polymers: examples of natural and manufactured polymers.			■			
Three Physical States of Matter: shows three states of matter (solid, liquid, and gas) using water as an example.			■			■
Types of Matter : diagrams and facts about elements, compounds, and mixtures.		■	■			

DNA Extraction					■		■	■					■
Dye Detective				■	■								■
Foam Peanuts					■					■	■		
Inner Space				■								■	■
Kool Colors						■	■						
Latent Prints				■									
Lost Labels		■	■			■							
Matter of Degree				■								■	
Odors Aloft				■								■	
Of Cabbages and Kings	■	■			■	■							
Penny for Your Thoughts		■	■	■		■							
Pollution Diffusion	■								■				
Reaction: Yes or No?		■				■							
Salting Out				■									
Sticky Situation		■			■	■		■			■	■	

Process Skills

The activities in this book encourage the use of the science process skills listed. The first three skills (Observing, Communicating, Questioning) are considered part of every activity and are therefore not listed in the introductory section of the activity. Skills are listed in increasing order of complexity.	Bend a Carrot	Big Things Come in Little Packages	Choose Your Ooze	Cleaning with Dirt
Observing: using one or more of the senses to obtain information about objects or events	■	■	■	■
Communicating: giving or receiving information or ideas	■	■	■	■
Questioning: forming a topic to investigate	■	■	■	■
Comparing and Contrasting: relating objects or events to each other based on similarities or differences	■	■		■
Describing and Defining: recording qualitative data through drawing, labeling, writing and/or observations	■			
Measuring: using standard or arbitrary units to quantify characteristics of objects or events		■		
Predicting: forming an idea of an expected result of an event or phenomenon				
Classifying: grouping or ordering objects or events according to common characteristics			■	
Making Models: developing a physical or mental representation to explain an idea, object, or event				■
Hypothesizing: stating a problem to be solved in the form of a testable question				■
Organizing Data: transforming recorded data into tables, graphs, schematics, or flow charts or mathematically analyzing data		■		
Analyzing: finding patterns in observations, data, or calculations and finding exceptions to those patterns (sources of error)			■	
Controlling Variables: changing one factor that may affect an event or phenomenon while holding all other factors constant	■		■	■
Inferring: forming an idea or prediction based on observation, evaluation, and judgment of past experience			■	
Explaining: using data, theories, models, and scientific principles to support claims	■			
Evaluating: judging the reasonableness of results; comparing results to expected values or explanations		■		

Color Me Blue	Density Rainbow	DNA Extraction	Dye Detective	Foam Peanuts	Inner Space	Kool Colors	Latent Prints	Lost Labels	Matter of Degree	Odors Aloft	Of Cabbages and Kings	Penny for Your Thoughts	Pollution Diffusion	Reaction: Yes or No?	Salting Out	Sticky Situation
■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
							■		■			■				
		■		■						■	■			■	■	■
	■					■		■	■					■		■
■	■				■							■			■	
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		■			■									■	■	
		■				■		■		■						

Resources

This list is up to date as of press time. To see the latest version of this document, and to use the Web links directly, visit **www.omsi.edu/k8chemistry**.

Bend a Carrot

Web—http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The Journal of Chemical Education publishes online lesson plans for high school students on multiple topics. Under the topic, Biochemistry, the lesson by Bertoluzzo, et al. investigates osmosis. The first half of the investigation requires advanced technique and chemicals. The second investigation is appropriate for younger students. Students observe onionskin under a microscope as water and saltwater solutions are added.

Web—http://www.tvdsb.on.ca/westmin/science/sbi3a1/cells/osmosis.htm
Good graphics about the process of osmosis in hypertonic, hypotonic, and isotonic solutions.

Web—http://www.carrotmuseum.co.uk
An extensive site about carrots, their history, their cultivation, nutritional value, and literary references. Contains many links to external sites as well as detailed information on the site.

Big Things Come in Little Packages

Great Explorations in Math and Science (GEMS), *Discovering Density*, Lawrence Hall of Science
Target level: 6th to 10th grade
This teachers' manual includes five 25- to 50-minute lessons and possible follow-up lessons. Each activity is well designed, includes detailed instructions, handouts, and data tables.

Choose Your Ooze

Web—http://www.omsi.edu/flubber
The official OMSI recipe for making Flubber.

Web – http://www.chemheritage.org/educationalservices/faces/poly/activity/resin.htm
This Web site contains specific chemical information about the reaction between Borax and glue. Gives more suggestions for making Flubber, which is called Glüg in the site. The images of the polyvinyl acetate and the cross-linked polyvinyl acetate and borate ions come from this site.

Web—http://www.youtube.com/watch?v=fazPiaHvFcg
This video, "Kid Science Episode 1: Cornstarch Suspension" is one of the favorites in the Chemistry Lab at OMSI. The host, Blake (age ~9), makes a suspension of cornstarch in water and explores some of its properties. He also discusses the three types of matter. We eagerly wait for future episodes from this young scientist.

Web—http://www.youtube.com/watch?v=yHIAcASsf6U
This video titled "People Run on a Pool of Oobleck" shows two men running across a suspension of cornstarch in water. The pool is about 3 feet deep, and you can see how the suspension compresses under their weight under high force. This video is not in English but still quite entertaining.

Choose Your Ooze (continued)

Dr. Seuss, *Bartholomew and the Oobleck*
Reading level: Kindergarten to 4th grade
This is a sequel to *The 500 Hats of Bartholomew Cubbins*, a page to King Derwin in the kingdom of Didd. King Derwin orders something more interesting to fall from the sky and gets Oobleck, a sticky, green substance. Discusses the importance of owning up to your mistakes.

Cleaning with Dirt

Web—http://pbskids.org/zoom/activities/sci/waterfilter.html
Web site gives directions on making a water filter similar to the one modeled here. Kids are encouraged to write in to the site and share their results.

Web—http://www.metro-region.org/
Metro is the regional government for the 3 counties and 25 cities in the Portland metropolitan area. At the bottom right is a link "for kids and schools" which describes lessons and videotapes available for teachers.

Web—http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf
The Environmental Protection Agency has good information about urban runoff.

Morrison, Gordon, *Pond*
Reading level: 3rd to 6th grade
Uses attractive ink drawings to describe the life cycle of a pond. Includes factual text about the animals and plants that live in a healthy pond.

Josephs, David, *Lakes, Ponds, and Temporary Pools (Exploring Ecosystems)*
Reading level: 5th to 8th grade
This activity book allows students to study a local pond. Includes detailed information about ponds and how sensitive they are to environmental factors. Also includes dichotomous keys to identify organisms living in the pond.

Color Me Blue

Web—http://www.cfsan.fda.gov/~lrd/colorfac.html
The FDA's frequently asked questions about food colors.

Density Rainbow

Web—http://antwrp.gsfc.nasa.gov/apod/ap001127.html
This satellite picture of the Earth at night shows how people are distributed around the world. The lit areas are densely populated cities.

Web—http://www.census.gov/population/www/censusdata/density.html
Many links to population data of cities and states. Some have calculated density, some have data for calculation.

Web—http://www.hometrainingtools.com/articles/exploring-liquid-density-newsletter.html
More activities for studying the density of liquids.

Web—http://www.exploratorium.edu/climate/primer/hydro-p.html
Good article explaining ocean currents and their role in climate change. Shows pictures of ocean currents and describes how salt concentration and temperature play a role.

Density Rainbow (*continued*)

Great Explorations in Math and Science (GEMS), *Discovering Density*, Lawrence Hall of Science
Target level: 6th to 10th grade
This teachers' manual includes five 25- to 50-minute lessons and possible follow-up lessons. Each activity is well designed and includes detailed instructions, handouts, and data tables.

DNA Extraction

Web—http://learn.genetics.utah.edu/units/activities/extraction/
This site has excellent pictures of the extraction process with diagrams of how detergent breaks apart fats and cell membranes, as well as where in the cell the DNA is stored. The Frequently Asked Questions section has additional information.

Web—http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The *Journal of Chemical Education* publishes online lesson plans for high school students on multiple topics. Under the topic, "Biochemistry," the lesson "Liver and Onions" uses a more complicated procedure to extract DNA.

Balkwill, Frances R., *DNA is Here to Stay*
Reading level: Kindergarten to 4th grade
This gives a simple explanation of what DNA is and what it does in the body. This author also writes a series called "Enjoy Your Cells." This book is scientifically accurate and good for all ages.

Walker, Richard, *Genes and DNA*
Reading level: 4th to 8th grade
This book explores modern genetics, from an investigation of genes and their function to forensics, gene therapy, and cloning.

Claybourne, Anna et al., *Usborne Internet Linked Introduction to Genes and DNA*
Reading level: 4th to 8th grade
Beautiful artwork takes you deep inside a cell. This book also explains genetically modified foods, the Human Genome Project, gene therapy, designer babies, and DNA testing.

Watson, James D., *The Double Helix: A Personal Account of the Discovery of the Structure of DNA*
Reading level: 10th to 12th grade
This is an autobiographical account from one of the discoverers of the structure of DNA. Tends to be a bit dramatic.

Maddox, Brenda, *Rosalind Franklin: The Dark Lady of DNA*
Reading level: 10th to 12th grade
Rosalind Franklin conducted crucial research that led to the discovery of the double helical structure of DNA. Because of her unpublished data and photographs, Francis Crick and James Watson were able to publish their work on the structure of DNA.

Dye Detective

Web—http://www.kids.union.edu/classroomActivities.htm
Lists many activities for classrooms by concept. Under chromatography, two activities link chromatography to books, *Rainbow Crow* and *The Very Hungry Caterpillar*.

Walker, Pam and Wood, Elaine, *Crime Scene Investigations: Real Life Science Activities for the Elementary Grades*
Reading level: 3rd to 6th grade
A teacher resource book containing instructions for 60 different activities related to Technology, Earth, Life, and Physical Science. Students investigate and solve crimes through scientific activities.

Carr, Mary, *One-Hour Mysteries* and *More One-Hour Mysteries*
Reading level: 4th to 8th grade
Each book provides instructions for teachers and students to solve 5 different mysteries. Focuses on logic as well as scientific principles to solve crimes

Foam Peanuts

Web—http://www.worldwise.com/biodegradable.html
Even though things are biodegradable, they may not break down in a landfill. Since a landfill has many layers, air and water cannot get to all items to help them break down. This site discusses this issue and includes a table of the degradation times of common materials.

Web—http://www.worldcentric.org/store/bioplastics.htm
Styrofoam and most plastics are made from petrochemicals (oil and gas). Bioplastics are created from plant materials, a potentially renewable resource. They are more likely to break down than traditional plastic, depending upon landfill conditions.

Showers, Paul, *Where Does the Garbage Go?*, Harper Trophy Publishing
Reading level: Kindergarten to 3rd grade
Clearly written and accessible to young children, the book explains what happens to solid waste, what goes into landfills, and how aluminum, newspapers, glass bottles and jars, and plastics are recycled today.

Gibbons, Gail, *Recycle! A Handbook for Kids*, Little, Brown Young Readers
Reading level: 2nd to 5th grade
A very readable and well-organized offering that's filled with information. Gibbons' cartoons in primary shapes and colors graphically illustrate the contents of a landfill and how to recycle various products to cut down on the need for landfills—which in some areas are in short supply. Discussing paper, plastic, glass, cans, and polystyrene, the author describes how and why to recycle, as well as the benefits of recycling.

Inner Space

Web—http://www.middleschoolscience.com/suface.htm
The general Web site features many science lesson plans. This lesson plan (under Chemistry) explores the surface tension of water by counting how many drops of water will fit on a penny. The Web site address really does have "surface" misspelled.

Kool Colors

Web—http://www.chemguide.co.uk/physical/basicratesmenu.html#top
A great Web site with sections on all areas of reaction rates: theories, causes, factors, etc.

Web—http://jchemed.chem.wisc.edu/HS/classact/ClassActsList.html
The activity "A Kool Reaction from the Fine Print" on this page provides an alternative version of this activity, along with student questions and further information on the chemistry behind the reaction. Scroll down to the link and click through to the PDF file.

Delamare, Guineau and Francois, Ber, *Colors: The Story of Dyes and Pigments*
Reading level: 6th to 8th grade
This small book details the history and uses of colors over the ages, from cave paintings to medieval alchemy to modern textiles. It is packed with colorful pictures and small anecdotes about color, dye making, and the use of pigments.

Latent Prints

Web—http://www.fbi.gov/hq/cjisd/iafis.htm
The Integrated Automated Fingerprint Identification System, a national fingerprint and criminal history system maintained by the Federal Bureau of Investigation (FBI).

Web—http://www.hcso.tampa.fl.us/SOD/ffingerprintid.htm
A Web site on fingerprint identification run by the Federal Bureau of Investigation (FBI).

Web—http://www.ridgesandfurrows.homestead.com/early_pioneers.html
Web site lists the biographies of early pioneers of the study of fingerprinting, including Henry Faulds, Francis Galton, and Sir William Herschel.

Web—http://www.bbc.co.uk/history/historic_figures/faulds_henry.shtml
Details the story of Henry Faulds, Francis Galton and Sir William Herschel and the conflicting claims of who was responsible for first using fingerprinting as a means of identification.

Emberly, Ed, *Ed Emberly's Fingerprint Drawing Book*
Reading level: all ages
An amazing number of drawings and figures created using fingerprints and a pen.

Jones, Charlotte, *Fingerprints and Talking Bones*
Reading level: 5th to 8th grade
Never gory or gross, and often even funny, especially when explaining things such as the reason police analyze a murder victim's stomach contents. Includes a glossary, cool crime facts, and a bibliography.

Great Explorations in Math and Science (GEMS), *Fingerprinting,* Lawrence Hall of Science
Reading level: 4th to 8th grade
Detailed plans for three class sessions, fully supported with handouts and answer keys, including fingerprint samples. Recommended by NSTA.

Lost Labels

Web—http://www.fi.edu/tfi/units/life/classify/classify.html
This Web site has many ideas for classification exercises using plants and animals. It suggests properties to use to group species. Lessons can be used for all ages.

Web—http://www.linnean.org/
The Linnean Society of London is concerned with taxonomy, which involves the examination and collection of a wide range of scientific evidence for accurate identification that is essential to any research. The Society finds much importance in identification of species for biodiversity conservation. Information about Carl Linnaeus, the founder of modern taxonomy, can be found on the site by choosing History from the main page.

Watts, Tom, *Pacific Coast Tree Finder*
Reading level: 3rd grade to adult
This is a classic key to identifying the native trees of the Pacific Coast, from British Columbia to Baja California. It uses characteristics such as leaf shape, tree height, and geographical location to determine the species of tree. It also includes pictures for easier identification. This book uses a dichotomous key format for accurate identification. The *Finders* series of pocket guides also includes guides to identify flowers, berries, mammals, and ferns.

Dussling, Jennifer, *Looking at Rocks*
Reading level: 1st to 4th grade
This is a great introduction to rocks and rock hounding. The pictures are clear and enhance the text, which is written at a good level for beginning readers.

Matter of Degree

Lerangis, Peter, *Antarctica: Journey to the Pole*
Reading Level: 3rd to 8th grade
An exciting novel packed with thoroughly researched information. Each chapter told from a different crew member's point of view.

Raskin, Lawrie, *52 Days by Camel: My Sahara Adventure*
Reading Level: 4th to 8th grade
Photographer Lawrie Raskin traveled to Timbuktu from Fez on a series of excursions riding buses, jeeps, trucks, a train, and a camel. Lively narrative. There are maps for each leg of the journey that are color coded with dots that match accompanying text. Also includes cultural information about survival in this extreme environment. Clear, bright, full-color photos abound.

Ryan, Zoe Alderfer, *Ann and Liv Cross Antarctica: Dream Come True*
Reading Level: 3rd to 8th grade
A factual account of the Bancroft Arnesen Expedition across Antarctica aimed at ages 9–12.

Forgey, William, *Basic Essentials: Hypothermia*
Reading Level: 4th to 8th grade
An information-packed tool for the novice or handy reference for the veteran. Distills years of knowledge in an affordable and portable book.

Of Cabbages and Kings

Web—http://scifun.chem.wisc.edu/chemweek/fallcolr/fallcolr.html
Anthocyanins are responsible for the beautiful reds and oranges in autumn leaves. This site explains the chemistry of these color changes and includes discussions of other colored plant pigments like carotenes and chlorophyll.

Web—http://en.wikipedia.org/wiki/Acid-base_indicator
A good introductory Web site to the topic, with a list of flowers and plants that contain acid-base indicators.

Odors Aloft

Cole, Joanna, *You Can't Smell a Flower With Your Ear!,* Grosset & Dunlap
Reading level: 1st to 4th grade
How do your ears hear? Will food taste the same if you hold your nose? A fun and simple science book—with games and experiments kids can do to test and trick their five senses—by the bestselling author of the *Magic School Bus* series.

Meisel,Paul, Weidner Zoehfeld, Kathleen, *What Is the World Made Of? All About Solids, Liquids, and Gases*, Harper Trophy
Reading level: 1st to 4th grade
A fact-filled, accessible study of solids, liquids, and gases. The book gives examples of each state of matter and some simple activities that demonstrate the attributes of each.

Cho, Shinta, *The Gas We Pass: The Story of Farts (My Body Science)*, Kane & Miller Publishers
Reading level: Kindergarten to 6th grade
This title, which explores all forms of flatulence, is "both informative and blunt," said Publisher's Weekly. "The book provides young readers with solid facts as well as plenty to snicker about."

Penny for Your Thoughts

Web—http://www.jmckinley.com/us/metal-reactions.htm
Detailed discussion of silver jewelry and its reactions.

Web—http://electronics.howstuffworks.com/battery.htm
A detailed description of how batteries work. Good diagrams.

Web—http://www.energizer.com/learning/science/
Directions on making electrical circuits and batteries.

Web—http://www.unr.edu/sb204/geology/mas.html
This is a simplified table showing the comparative reactivity of different metals. Notice that iron is higher on the list than copper, so it is more reactive and allows copper to take its place on the paper clip.

Mathis, Sharon Bell, *The Hundred Penny Box*
Reading level: 4th to 8th grade
Michael's great-great-aunt Dew has a box with a penny for every year of her life. She spends time with Michael telling stories about each of the hundred years of her life. Winner of a Newberry Honor.

Pollution Diffusion

Web—http://www.epa.gov/safewater/kids/wsb/
The United States Environmental Protection Agency maintains a Web site with information and educational activities. The Water Sourcebooks contain 324 activities for grades K–12. The chapters labeled "Ground Water Resources" have activities and information relevant to this activity.

Web—http://www.hanford.gov/orp/
The Hanford Site—Office of River Protection. Closing the nuclear waste tanks to protect the Columbia River.

Web—http://www.deq.state.or.us/wmc/tank/lustlist.htm
Oregon Department of Environmental Quality lists 500 pages of sites for leaking underground storage tanks. County, street address, city, dates of cleanup are listed.

Web—http://www.ecy.wa.gov/programs/tcp/ust-lust/tanks.html
Washington State Department of Ecology maintains a list of LUST sites. Sorted by county, the 600-page list contains city, latitude, longitude, and cleanup status of storage tanks.

Web—http://www.deq.state.id.us/waste/prog_issues/ust_lust/index.cfm
Idaho Department of Environmental Quality has two lists of LUST and UST sites. Lists have city, zip code, and clean-up status listed.

Kramer, Stephen P., *How to Think Like a Scientist: Answering Questions by the Scientific Method*
Reading level: 4th to 7th grade
Humorous and appealing pictures accompany explanations of how to use the scientific method to answer questions. Also points out the problems encountered when the scientific method is not followed correctly.

Blanford, Millie and Camplair, Patience, *Teaching The Scientific Method: Instructional Strategies To Boost Student Understanding*
The lessons in this book enable students to solve problems using the scientific method, conduct research, use scientific equipment appropriately, construct and explain tables, graphs, and reports, and develop experiments independently.

Reaction: Yes or No?

Web—http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The *Journal of Chemical Education* publishes online lesson plans for high school students on multiple topics. Under the topic, Consumer Chemistry, the lesson "Meltdown Showdown! Which Deicer Works Best?" investigates the effectiveness of different brands of deicers.

Web—http://www.chem4kids.com/files/react_intro.html
A brief overview of chemical reactions with colorful pictures that show atoms from different molecules combining and rearranging to form new substances.

Color Changing Paper
Available at most Kinko's stores, this goldenrod paper is bright gold but will change to bright red when exposed to base. It contains the same dye, curcumin that makes the turmeric change color in this experiment. The brand is Wausau Papers, Astrobrights, Galaxy Gold.

Scientific Inquiry

Web—http://en.wikipedia.org/wiki/Dependent_and_independent_variables
A good introduction to dependent and independent variables with various examples.

Web—http://www.nwrel.org/mec/science_inq/index.html
This is the Northwest Regional Educational Laboratory Science Inquiry Model Web site. This is a thorough site that supplies teachers with definitions of science inquiry, scoring guides, teaching strategies, and resources.

Web—http://www.nsta.org/about/positions/inquiry.aspx
This site has the official position about Scientific Inquiry from the National Science Teachers Association.

Web—http://www.ode.state.or.us/teachlearn/real/standards/default.aspx
The Oregon Department of Education Web site has many resources for teachers. To get specific information about scientific inquiry standards (choose the subject "Science" and search for the strand "Scientific Inquiry").

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The lessons in this book enable students to solve problems using the scientific method, conduct research, use scientific equipment appropriately, construct and explain tables, graphs, and reports, and develop experiments independently.

Worth, Karen and Grollman, Sharon, *Worms, Shadows, and Whirlpools: Science in the Early Childhood Classroom*
This book furthers the notion that even the littlest learners are powerful thinkers. Identifies important skills and concepts appropriate for the very young. Contains many examples of teacher stories, children's work, and commentary.

Chaille, Christine and Britain, Lory, *The Young Child as Scientist: A Constructivist Approach to Early Childhood Education, 3rd Edition*
The authors of this book focus on how children have "wonderful ideas" and, when collaborating, can use a social process to construct meaning from experiences. Practical examples and theory are presented.

Salting Out

Web—http://en.wikipedia.org/wiki/Polar_molecule
An introduction to the concept of polar and non-polar molecules, with pictures and diagrams.

Web—http://chem4kids.com
An excellent Web site with information on all chemical concepts. Their site map has a well-organized topic index. The topics "Solutions," "Mixtures 1," and "Mixtures 2" are relevant to this activity.

Web—http://www.saltinstitute.org/38.html
The Salt Institute has an extensive site explaining the place salt has in history, politics, and economics.

Frankel, Jill and Kline, Michael, *Super Science Concoctions: 50 Mysterious Mixtures for Fabulous Fun*
Reading level: 3rd to 8th grade
Well-organized, detailed recipes, fun activities, and thorough, accurate scientific explanations. The first section focuses on solutions and mixtures; later sections explore other chemistry topics.

Sticky Situation

Web—http://solutions.3m.com/en_US/
The Minnesota Mining and Manufacturing (3M) Company started out making sandpaper and now makes every type of tape, label, glue, and sticker imaginable. If you are having trouble thinking of different kinds of adhesives, take a look at their product line.

Web—http://www.3m.com/intl/uk/3mstreetwiseuk/teachers_landing_page.htm
The 3M Company has a curriculum about safety that is free for teachers. Use this link to request teaching materials.

Cleeland, Holly, *Glue & Go Costumes for Kids: Super-Duper Designs with Everyday Materials*
Using just a glue gun and easy-to-find materials (fabric, cardboard boxes, plastic cups, foam core), you can make unique costumes. Book includes full-color photographs.

Wolf, Allan, *Haiku Stickies: 100 Haiku to Write & Leave Behind*
A pad of partial haiku poems is included with this book. Each poem has blank spaces for children to fill in; earlier in the pad, they'll need to add only a word or two, while the later haiku will have kids writing nearly from scratch.

Science Topics

Below is the list of main science topics covered by the activities in this book. The topics are separated into eight categories (in bold). These Science Topics are listed in the introductory section of each activity.

	Bend a Carrot	Big Things Come in Little Packages	Choose Your Ooze	Cleaning with Dirt
Physical Properties: properties of solids, properties of liquids, properties of gases, phase changes, density, conductivity, magnetism		■	■	
Atoms and Molecules: atomic structure, protons, neutrons, electrons, periodic table, ions, elements, chemical bonds, polymers	■			
Solutions and Mixtures: miscibility, solubility, diffusion, concentration, purification, emulsions, alloys, acids and bases				■
Techniques: scientific method, measuring, data collection, chromatography, distillation, titration, filtration	■	■		■
Chemical Reactions: signs of reaction, rates of reaction, types of reaction, energy, stoichiometry, conservation of matter, limiting reactants, catalyst			■	
Organic and Biochemistry: proteins, carbohydrates, DNA, fats and oils, photosynthesis, fermentation, osmosis, chemiluminescence	■			
Environmental and Geochemistry: water quality, air quality, recycling, pollutants, minerals, metallurgy				■
Industrial Chemistry: synthesis, electrochemistry, plastic, liquid crystals, computers, nanotechnology, electrolysis			■	

Color Me Blue		■		■	■			
Density Rainbow	■	■	■					
DNA Extraction			■	■		■		
Dye Detective		■	■	■				
Foam Peanuts			■		■		■	
Inner Space		■		■				
Kool Colors			■	■	■			
Latent Prints	■	■				■		
Lost Labels	■				■			
Matter of Degree	■		■		■			
Odors Aloft	■	■						
Of Cabbages and Kings	■			■	■			
Penny for Your Thoughts		■			■			■
Pollution Diffusion			■	■			■	
Reaction: Yes or No?	■		■		■			
Salting Out	■	■	■					
Sticky Situation		■			■			■

Activities for Visually Impaired Students

The following list contains those classroom and take-home pamphlet activities that would work well with visually impaired students (with a sighted assistant). The activities all include experiences with sound, touch, or smell in some way.

Classroom Activities:

Take-Home Activities: