Investigation 2
Physical properties and physical change in solids

How can you tell if crystals that look the same are really the same or different?

Summary
In this investigation, students compare the properties of four different household crystals to the properties of an unknown crystal. This unknown crystal is chemically the same as one of the known crystals, but does not appear the same. Students conduct tests for appearance, “crushability”, solubility, and recrystallization to help them identify the unknown crystal. The activities emphasize solubility as a characteristic property of a solid, identifying and controlling variables to design fair tests, making observations, and analyzing results.
Investigation 2: Physical properties and physical change in solids

Key concepts for students
- Solubility is a characteristic property of a substance.
- To measure equal amounts of different solids for a solubility test, it is better to use mass than volume.
- When comparing solubilities of different solids, all variables should be kept the same except for the type of solid used.
- The way a substance recrystallizes is a characteristic property of that substance.
- Solubility and recrystallization can be used to help identify an unknown substance.

Learning objectives
Students will be able to:
- Develop an understanding of the meaning of characteristic properties of substances by testing and comparing different household crystals.
- Recognize that solubility is a characteristic property of a substance.
- Identify an unknown crystal by comparing its characteristic physical properties with those of four known crystals.
- Measure equal amounts of crystals by mass rather than volume.
- Identify possible variables and suggest ways to control them as they help design valid scientific investigations.

Investigation questions
How can you tell if crystals that look the same are really the same or different?
- Can you identify an unknown crystal by comparing its appearance to other known crystals?
- Can you identify the unknown crystal by crushing the different crystals and comparing them?
- Do some of the crystals dissolve more or less than others?
- What is the best way to measure equal amounts of crystals?
- Can you identify the unknown crystal by the amount that dissolves in water?
- Can you identify the unknown crystal by the way it looks when it recrystallizes?

Assessment
The assessment rubric Physical properties and physical change in solids, pp. 108–109, enables teachers to document student progress as they design and conduct activities and complete the activity sheets. Students will demonstrate their understanding of both the physical science and inquiry content as they complete the activity, readings, and worksheets in the Review and apply section on pp. 110–124.
Relevant *National Science Education Standards*

**K–4**

**Physical science**

**Properties of objects and materials**

Objects have many observable properties, including size, weight, shape, and color.

**Science as inquiry**

**Abilities necessary to do scientific inquiry**

Ask a question about objects.
Plan and conduct a simple investigation.
Use simple equipment and tools to gather and extend the senses.
Use data to construct a reasonable explanation.
Communicate investigations and explanations.

**Understandings about scientific inquiry**

Scientific investigations involve asking and answering a question.
Types of investigations include describing objects…and doing a fair test.
Good explanations are based on evidence from investigations.

**5–8**

**Physical science**

**Properties and changes of properties in matter**

Substances have characteristic properties, such as density… and solubility.

**Science as inquiry**

**Abilities necessary to do scientific inquiry**

Identify questions that can be answered through scientific investigations.
Design and conduct a scientific investigation.
Use appropriate tools and techniques to gather, analyze, and interpret data.
Develop descriptions, explanations, predictions, and models using evidence.
Think critically and logically to make the relationships between evidence and explanations.
Communicate scientific procedures and explanations.

**Understandings about scientific inquiry**

Different kinds of questions suggest different kinds of scientific investigations.
Scientific explanations emphasize evidence and have logically consistent arguments.
Scientific investigations sometimes result in new ideas and phenomena for study that can lead
to new investigations.
Materials chart for student activities

2.1  Curious crystals
2.2  Crushing test
2.3  Solubility test
2.4  Recrystallization test

<table>
<thead>
<tr>
<th>Each group will need</th>
<th>2.1</th>
<th>2.2</th>
<th>2.3</th>
<th>2.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt in cup</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Epsom salt in cup</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
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<tr>
<td>MSG (Accent®) in cup</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Sugar in cup</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Kosher salt in cup (unknown)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Black construction paper, ½ piece</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnifying glass</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masking tape</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pen</td>
<td>●</td>
<td></td>
<td></td>
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<tr>
<td>Ruler</td>
<td></td>
<td></td>
<td>●</td>
<td></td>
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<tr>
<td>Permanent marker</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Clear plastic cups</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Small plastic cups, 3½ ounces</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Plastic teaspoon</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Hot tap water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper clips</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Cotton swabs</td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Crystal solutions from Activity 2.3</td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>

Notes about the materials

- Be sure you and the students wear properly fitting goggles.
- Students should use care when handling hot tap water.
- Standard metal paper clips weigh about 0.4–0.5 grams each. Students should use 10 identical paper clips to measure either 4 or 5 grams of each crystal. Either 4 or 5 grams of each crystal is enough to observe differences in solubility.
- Additional materials will be required for the Review and apply: Science in action! activity, pp. 113–115. These include potassium chloride which can be purchased under the brand name Nu-Salt®.
Materials chart for teacher demonstrations

2a. Solubility is a characteristic property
2b. Measuring equal amounts of crystals for the solubility test

<table>
<thead>
<tr>
<th>Demo 2a</th>
<th>Demo 2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead projector</td>
<td>Primary balance</td>
</tr>
<tr>
<td>Transparency</td>
<td>Primary balance</td>
</tr>
<tr>
<td>Transparency marker</td>
<td>Clear plastic cups</td>
</tr>
<tr>
<td>Clear plastic cups</td>
<td>2</td>
</tr>
<tr>
<td>Salt</td>
<td>Zip-closing plastic bag,</td>
</tr>
<tr>
<td>Sugar</td>
<td>quart-sized</td>
</tr>
<tr>
<td>Hot tap water</td>
<td>Ball-shaped cereal</td>
</tr>
<tr>
<td>Teaspoon</td>
<td></td>
</tr>
<tr>
<td>Scale to weigh 5 grams</td>
<td></td>
</tr>
</tbody>
</table>

Notes about the materials

- If you do not have a scale that can weigh 4 or 5 grams, build a balance using a ruler, pencil, tape, cups, and 10 paperclips as described in Activity 2.3—Solubility test, p. 95.

- You will need enough ball-shaped cereal to completely fill two plastic cups.
Science background information for teachers

The physical properties of a solid are characteristics such as shape, color, size, and texture. Some other physical properties that are not as readily observable are density and hardness.

Sometimes, these physical properties can change. A physical change is a change that alters the form or appearance of a substance without changing the chemical composition. One example of physical change is melting: A substance changes from a solid to a liquid. Another is breaking apart and dissolving in a liquid to become part of a solution. In both cases, the substance changes its form or size but does not change its identity. The physical properties of substances, like the crystals examined in this investigation, and the way they undergo physical change are characteristic properties and can be used to distinguish one substance from another.

For videos, animations, and other information related to this investigation, go to www.inquiryinaction.org

Chemistry concepts

- A water molecule has an area of positive charge and an area of negative charge.
- Salt (sodium chloride) is made up of positive and negative ions.
- Dissolving salt depends on the interaction between water molecules and the sodium and chloride ions.
- If the attraction the water molecules have for the sodium and chloride ions overcomes the attractions these ions have for each other, dissolving can take place.
- The solubility of a substance depends on the ions or molecules it is composed of, how strongly they are attracted to each other, and how they interact with water molecules.

Activity 2.1—Appearance test

There are two main reasons why the various types of crystals look different from one another. One reason is that the crystals are made of different atoms and molecules. Since the atoms and molecules are different, the way in which they bond together to form the crystal varies. This atomic and molecular structure affects the crystal’s overall shape, color, texture, and other features. The other factor that can affect the appearance of the crystals is the way they are processed and packaged for sale. The table salt (sodium chloride) and the kosher salt (sodium chloride) are chemically the same but look different because of the way they are processed. Both salts are produced by pumping water into rock salt deposits and then collecting the salty water and evaporating it. To make kosher salt, the salty water is continuously raked during the evaporation process, which results in less uniform and flakier salt crystals.

Activity 2.2—Crushing test

The hardness of the crystals is mostly dependent on their atomic and molecular structure. But, as mentioned above, the processing of the crystals may also have an impact on their properties, including hardness. This crushing test is not the classic hardness test that geologists use to help them identify minerals. It is a much more subjective test that has several variables that are difficult to control, which makes it a fairly unreliable test. It is included as an activity mainly because students may suggest crushing the crystals as a way to help identify them. Also, a discussion that identifies variables and considers why they are hard to control can help students better appreciate the issues involved in designing a valid experiment. The main
variables that are difficult to control here are the crystal size and the force applied to the crystals. After doing the test and discussing the problems concerning certain variables, students will probably not be able to conclusively identify the unknown, or even eliminate any crystals based on this test.

**Demonstration 2a—Solubility is a characteristic property**

Solubility is usually expressed as the maximum number of grams of a substance that can be dissolved in 100 ml of water at a certain temperature. Since this number is unique for each substance, solubility is a characteristic property of a substance. In this demonstration, you will show students that more sugar than salt will dissolve in the same amount and temperature of water. Once students see that sugar is more soluble than salt, they will realize that dissolving each of their crystals in water may reveal distinct enough differences to help them identify the unknown crystal.

The graph at the right shows the solubility curves for salt (sodium chloride) and sugar (sucrose) over a range of temperatures. Solubility, as shown on the graph, is measured as the maximum number of grams of a substance that will dissolve in 100 ml of water at a given temperature. This is the saturation point of a substance. So, each point on the graph shows the saturation point of salt or sugar at a given temperature. For example, at room temperature (20 °C) about 37 grams of salt and about 195 grams of sugar can be dissolved in 100 ml of water. Since solubility is a characteristic property, every substance has its own unique solubility curve.

An interesting thing to note about the solubility of salt is that it does not increase very much as the temperature is increased. In *Demonstration 4a—Temperature affects the solubility of salt and sugar*, pp. 196–201, students will compare the amounts of salt and sugar that dissolve in cold and hot water.

**Demonstration 2b—Measuring equal amounts of crystals for the solubility test**

For a dissolving test it is important to use the same amount of each type of crystal. Students may suggest using a volume measure, like a teaspoon, or weighing the crystals. This demonstration shows that measuring the mass of the crystals is better than measuring the volume.

Using volume to measure the crystals is problematic. The size and shape of the crystals will affect how much room they take up in the spoon. If one type is very small and well-packed in the spoon and the other is larger and packed more loosely, it is likely that a level teaspoon of each could contain a very different amount of crystal.

Mass is a better way to measure the same “amount” of each crystal. Used in this way, “amount” refers to the quantity of matter that makes up the crystals, rather than the space or volume the crystals take up. The amount of matter that makes up a substance is measured by its mass.
Activity 2.3—Solubility test
The reason why the different crystals dissolve differently has to do with the different size, weight, strength of attraction, and packing together of the ions or molecules that make up the crystal. The amount of attraction that the water molecules have for the particles of the substance compared to the attraction the particles of the substance have for each other determines the solubility of the substance. For the purpose of this activity, the solubility of a crystal is measured by the amount that dissolves in a teaspoon of hot water in about 1 minute.

Salt is made from positive and negative ions
Regular table salt is sodium chloride. Its chemical formula is NaCl. Na stands for sodium and Cl stands for chlorine. The sodium and the chlorine in salt are bonded to each other in a special way. In a reaction between a chlorine atom and a sodium atom, an electron is transferred from the sodium to the chlorine. Since electrons have a negative charge, this gives the chlorine a net negative charge because it gained an electron. Losing an electron gives the sodium a net positive charge. This is because it has the same number of positive protons it had before but one fewer electron. When an atom gains or loses one or more electrons and then has a negative or positive charge, it is called an ion. Since positive and negative attract, positive sodium ions and negative chloride ions attract each other and bond together. This is what keeps the sodium and chloride ions together within a salt crystal.

The illustrations below show a salt crystal dissolving in water. Notice how the negative chloride ions are attracted by the positive ends of the water molecules (near the hydrogen atoms). And the positively charged sodium ions are attracted by the negative ends of the water molecules (near the oxygen atoms).

If students use the same mass of each crystal, the same amount and temperature of water, and swirl the solution in the same way for the same length of time, this should be a pretty fair test of the differences in solubility between the crystals. But there is still one variable that has not been controlled: the size of the crystals. The more surface area that is in contact with the water, the faster the crystal should dissolve. So for a given amount of crystal, the smaller it is crushed up to begin with, exposing a lot of surface area, the faster it will dissolve. Technically, to help reduce the effect of this variable, all crystal samples would have to be crushed to the same size. We do not recommend this step because of logistical difficulties in crushing the crystals to the same size.

**Activity 2.4—Recrystallization test**

The recrystallization test is like a “reverse-dissolving” test. When the different substances dissolve, their ions or molecules are surrounded by water molecules. This makes it hard for the ions or molecules to come together to begin to form a crystal again. But as the water evaporates, there are fewer water molecules surrounding the ions or molecules. Evaporation causes the concentration of the water to go down and the concentration of the solute to go up. This makes it easier for the ions or molecules to come together and bond according to their positive and negative charges, forming crystals.

Once the solutions have evaporated, the resulting crystals look different from one another. This is because they are made of different ions with different structures and sizes that bond together in different arrangements. Both the unknown (coarse kosher salt) and the table salt look alike when they recrystallize because they are both sodium chloride.

The sugar solution may not recrystallize even after a long period of time. One reason for this is that each substance has its own level of concentration it has to reach before it will recrystallize. Water takes a long time to evaporate from a sugar solution, so it takes a long time for the sugar to reach this concentration.
Activity 2.1
Curious crystals

Can you identify an unknown crystal by comparing its appearance to other known crystals?

In this activity, students will carefully look at four known household crystals. After observing and describing the crystals, students will be given an unknown crystal, which is chemically the same as one of the four known crystals but looks different. When students realize that they cannot identify this crystal by its appearance alone, they will suggest other tests and ways to compare the crystals to eventually identify the unknown crystal. The other activities in this investigation are examples of tests students can conduct on the crystals. After a series of these tests, students will gather enough evidence to identify the unknown crystal.

Materials needed for each group

Salt
Epsom salt
MSG (Accent®)
Sugar in cup
Kosher salt in cup (unknown)
5 Small cups
Black construction paper, ½ piece
Magnifier
Masking tape
Pen
Plastic spoon

Notes about the materials

● Be sure you and the students wear properly fitting goggles.
● The piece of black construction paper, and crystals poured on it, will be used in both Activities 2.1 and 2.2.

Preparing materials

● Use a permanent marker to label five small cups salt, Epsom salt, MSG, sugar, and unknown.
● Place at least 2 teaspoons of each crystal in its labeled cup.
● These source cups and crystals will be reused in Activities 2.2 and 2.3.

Activity sheet

Copy Activity sheet 2.1—Curious crystals, pp. 79–81, and distribute one per student when specified in the activity.

Assessment

An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.

Activity 2.1
Curious crystals

Question to investigate
Can you identify an unknown crystal by comparing its appearance to other known crystals?

Take a closer look
1. Have students read the introductory story on Activity sheet 2.1 and examine the crystals.

Introduce students to the four household crystals they will be examining. Then have students follow the procedure below and record their observations about the crystals on the activity sheet. Let students know that they can look at the crystals and touch them but they should not taste them!

Procedure

1. Use masking tape and a pen to label four corners of a piece of black construction paper: sugar, salt, Epsom salt, and MSG. Label the center unknown.

2. Place small samples of Epsom salt, table salt, sugar, and MSG on the labeled areas of the construction paper.

3. Use a magnifier to look carefully at each type of crystal.

4. Describe some characteristics of each crystal. Include any similarities and differences you notice among them.

2. Have students discuss their observations.
Students should describe physical properties such as the size, shape, color and texture. They should also describe whether the crystals are shiny, dull, transparent, or opaque.
Try this!

3. Introduce the “unknown crystal” and have students compare it to the four known crystals.

Give students a sample of the unknown crystal and tell them that this unknown is chemically the same as one of the other crystals they just looked at. Have them compare this unknown to the others as described in the following procedure.

Procedure

1. Place a sample of the “unknown crystal” in the center of your piece of black construction paper.

2. Use a magnifier to help you compare this crystal to each of the four crystals you just examined.

4. Discuss student observations.

Expected results: The unknown will not look identical to any of the other crystals.

Ask students for their ideas about what the unknown might be based on the way the crystals look. (Don’t tell students yet that the unknown is coarse kosher salt.) Ask students to identify crystals they think the unknown might be. Then ask them how certain they are that this is the identity of the unknown. Students should not have enough evidence to correctly identify the unknown at this point.

What’s next?

5. With the whole class, have students suggest tests they could do that might help them identify the “unknown crystal”.

Tell students that the appearance test did give some information about the crystals, but not enough to identify the unknown. Ask students for their ideas about other tests they could conduct that might reveal the identity of the unknown. One example of a test would be to crush each type of crystal to see if the unknown breaks in a way that is similar to one of the known crystals. Students might also suggest dissolving each of the crystals in water. Perhaps the unknown will dissolve as much as one of the known crystals. Tell students that in the next few activities they will help design tests and gather evidence to discover the identity of the unknown.
Curious crystals

I woke up the other day and went into the kitchen to get some breakfast. I usually make a waffle or cereal, and my dad usually makes eggs and coffee. My dad added some sugar to his coffee and put a little salt on his eggs. I saw that a few tiny bits of sugar and salt had dropped onto the table. I’d never really thought about it, but I noticed how similar the sugar and salt looked even though I know how different they taste. Anyway, I couldn’t think about sugar and salt too much because I had to catch the bus to school. At lunch that day, I had some pretzels and a sugar cookie and it happened again. There they were. I looked very closely at the salt granules on the pretzel and the sugar granules on the cookie. They almost looked like tiny crystals. When I got home that night, I took a little salt and sugar from the cabinet and looked at them with a magnifying glass. While I was at it, I asked if I could look at some other stuff that also looked like crystals. My mom gave me some MSG from the kitchen cabinet and some Epsom salt from the bathroom closet. I looked at all these with a magnifying glass and saw some pretty interesting things.

Take a closer look

Look at a few household crystals to see what you notice about them.

What do Epsom salt, table salt, sugar, and MSG crystals look like?

Procedure

1. Use masking tape and a pen to label four corners of a piece of black construction paper **Epsom salt, salt, sugar, and MSG**. Label the center unknown.

2. Place small samples of Epsom salt, table salt, sugar, and MSG on the labeled areas of the construction paper. (Be sure not to taste the crystals.)

3. Use a magnifier to look carefully at each type of crystal.

4. Describe some characteristics of each crystal in the chart on the following page. Include any similarities and differences you notice about them.
Student activity sheet
Activity 2.1
Curious crystals (continued)

Try this!
Your teacher gave you a crystal sample labeled unknown. This crystal is chemically the same as one of the four known crystals.

Can you identify the unknown crystal by comparing its appearance to other known crystals?

Procedure
1. Place a sample of an “unknown crystal” in the center of your piece of black construction paper.

2. Use a magnifier to help you compare this crystal to each of the four crystals you just examined.

1. What similarities do you notice between the unknown and any of the known crystals?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

2. Based on your observations, what do you think the identity of the unknown might be?

_____________________________________________________________________

3. How certain are you that your guess is correct?

_____________________________________________________________________

<table>
<thead>
<tr>
<th>Epsom salt</th>
<th>Salt</th>
<th>Sugar</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name: _____________________________
What’s next?

The appearance test gave you some information about the crystals, but probably not enough to identify the unknown for sure. So you will need to conduct a few other tests. One test could be to crush each type of crystal to see if the unknown breaks in a way that is similar to one of the known crystals. You may also try dissolving each of the crystals in water. Maybe the unknown will dissolve as much as one of the known crystals does. In the next few activities you will help design these types of tests as you try to discover the identity of the unknown.
Activity 2.2
Crushing test

Can you identify the unknown crystal by crushing the different crystals and comparing them?

A hardness test is used to identify rock samples, so a similar test may provide some information about the crystals. In this activity, students will try to design a crushing test and discover that identifying and controlling the variables may be difficult. Although the crushing test will not give conclusive results, it is a good opportunity to discuss variables and why they are sometimes difficult to control. This crushing test is also a good example of how a particular test does not always give enough information to answer a question.

Materials needed for each group
Salt in cup
Epsom salt in cup
MSG (Accent®) in cup
Sugar in cup
Kosher salt in cup (unknown)
Black construction paper, ½ piece
Plastic teaspoon

Notes about the materials
- Be sure you and the students wear properly fitting goggles.
- Use the crystals in labeled cups from Activity 2.1. These will be reused again in Activity 2.3.
- Use the piece of black construction paper labeled in Activity 2.1.

Activity sheet
Copy Activity sheet 2.2—Crushing test, pp. 85–86, and distribute one per student when specified in the activity.

Assessment
An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.
Activity 2.2
Crushing test

Question to investigate
Can you identify the unknown crystal by crushing the different crystals and comparing them?

1. Have students help design a fair test.

In Activity 2.1, students may have suggested crushing the crystals. Distribute Activity sheet 2.2—Crushing test so students can plan a crushing test. Then lead a class discussion so that students can suggest ways to compare the “crushability” of the crystals. Important considerations to elicit from students involve controlling variables such as using the same object to crush each pile of crystals and trying to use the same amount of force for the same length of time. Discuss the importance of keeping variables the same in an experiment so that the test is fair. As a class, decide on the materials and procedure the groups will follow. You and the students can, of course, decide to use a can, a rolling pin, or any other safe object and a safe method to apply a consistent amount of force to the crystals in the same way. The procedure below is just one possible experimental design. Be sure students wear safety goggles when crushing the crystals.

2. Have students conduct the experiment.

Students may use the crystals they placed on the black construction paper from Activity 2.1. If they do, they can skip Steps 1 and 2.

Procedure
1. Use masking tape and a pen to make a small label for each of the five crystals as shown.

2. Spread a little of each of the five crystals in their labeled areas on the black paper.

3. Use your thumb in the bowl of a plastic spoon to press down on each pile of crystals, as shown. Rock the spoon back and forth to help crush the crystals.

4. Listen to the sounds the crystals make as they break. Notice any difference in the way the crystals feel when they break. Compare the residue left behind on the black paper.
3. Have students share and interpret their results.

Have students record their ideas about the identity of the unknown on Activity sheet 2.2—Crushing test.

Ask the following questions:

- Can you single out any crystal that is definitely not the unknown?
- Are any crystals similar enough to the unknown that they might be the unknown?
- Do you have enough information from this crushing test to say that you definitely know the identity of the unknown?

**Expected results:** Although students may have detected slight differences in the crystals during the crushing test, they probably cannot identify the unknown at this point.

Ask students whether comparing the sound, feel, or residue from each crystal is the best way to identify the unknown. Students should recognize that problems using a consistent amount of force to crush each crystal would make this test inconclusive. Students should conclude that they need more information to identify the unknown.
Student activity sheet
Activity 2.2

Crushing test

Can you identify the unknown crystal by crushing the different crystals and comparing them?

If you were going to test and identify rock samples, you might use a hardness test. In a hardness test, you scratch a rock sample with different substances. If the rock gets scratched it means that it is not as hard as that substance. Hardness is a characteristic property of a rock. So knowing a rock’s hardness can help you identify it.

Since the household crystals you are working with are so small, they would be difficult to scratch. But you can crush the crystals and compare how they break. Are they easy to break? Do they make a certain cracking sound? Do they leave a certain mark on a surface? Do the crushed pieces look a certain way? If “crushability” is a characteristic property of a substance, you may get some information that could help you identify the unknown crystal.

Plan your crushing test

1. What is one way you could crush samples of crystals?
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

2. What would you do to make sure that you crush each crystal with the same amount of force so that the test is fair?
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

Conduct your crushing test
Interpret your observations

After you have conducted the crushing test, answer the following questions.

3. Can you single out a crystal that is definitely not the unknown?

_____________________________________________________________________

4. Which crystal or crystals might be the unknown?

_____________________________________________________________________

_____________________________________________________________________

5. Do you have enough information from this crushing test to say that you know the identity of the unknown for sure?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________
Demonstration 2a
Solubility is a characteristic property

Do some of the crystals dissolve more or less than others?

In this demonstration, students are introduced to the term solubility and the idea that solubility is a characteristic property of a substance. First, students will see that sugar is more soluble than salt. They can then reason that other crystals may also have different solubilities. In fact, a solubility test on all of the crystals may help them identify the unknown. Students begin to consider how they might conduct this solubility test using all of the crystals. However, they will encounter a problem when addressing how to the measure equal amounts of each crystal: Should they use a volume measure like a teaspoon or weigh the crystals? Demonstration 2b resolves this issue.

Materials needed for the demonstration

Overhead projector
Transparency
Transparency marker
2 Clear plastic cups
Salt
Sugar
Hot tap water
Teaspoon
Scale to weigh 5 grams

Notes about the materials

• Be sure you and the students wear properly fitting goggles.

Preparing materials

• Use a sensitive scale to measure 5 grams each of salt and sugar.
• If you do not have a scale that can weigh 5 grams, build a balance using a ruler, pencil, tape, cups, and 10 paperclips as described in Activity 2.3, p. 95. Ten paperclips typically weigh between 4 and 5 grams.
• Place a transparency on the overhead projector and label one area salt and another sugar.

Activity sheet

Copy Demonstration sheet 2a—Solubility is a characteristic property, p. 90, and distribute one per student when specified in the activity.

Assessment

An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.

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Demonstration 2a
Solubility is a characteristic property

Question to investigate
Do some of the crystals dissolve more or less than others?

1. **Discuss the variables in a solubility test.**

Tell students that salt and sugar are both crystals that dissolve in water. Ask them how they might design an experiment to compare how well sugar and salt dissolve. Use the following questions to get students to identify the variables in this demonstration:

   - In order to have a fair comparison, should we use the same amount of water in both cups when we try to dissolve the crystals?
   - What about the temperature of the water? Why is that important?
   - Should we use the *same* amount of each crystal? Why?
   - Should the cups be swirled in the same way and for the same length of time?

2. **As a demonstration, dissolve salt and sugar in water.**

Follow the procedure below while pointing out to students that you are using the same amount of water at the same temperature, and the same amount of crystal, swirled in the same way for the same length of time.

**Procedure**

1. Using identical clear plastic cups, place 1 teaspoon of hot tap water into each cup and place them on the overhead.

2. Place equal preweighed samples (about 5 grams) of salt and sugar into the cups of water at the same time. Swirl each cup at the same time and in the same way for about 20 seconds. Be sure to keep both cups on the overhead.

3. Ask students whether one substance seems to dissolve more than the other.

4. Swirl again for 20 seconds and observe. Then swirl for 20 more seconds and have students make their final observations.

5. Slowly and carefully pour the solution from each cup back into the empty labeled cups. Try not to let any undissolved crystal go into these cups. Place the clear plastic cups on the overhead so that students can compare the amount of undissolved crystal remaining.

**Expected results:** Much more sugar will dissolve than salt. There will be more salt than sugar left in the cup.
3. **Discuss the results of the demonstration.**

Ask students questions such as the following:

- Are the amounts left over the same?
- Which crystal has more left over?
- Where did the missing crystal go?
- Which dissolved better, salt or sugar?
- Do you think dissolving the five crystals in water might show differences between them?
- What makes you think that?
- How would you know which crystal is the same as the unknown?

Students should conclude that more sugar dissolved than salt when they compared the amount of each crystal left behind after three cycles of swirling. Since there was less sugar than salt left in the cup, this means that more sugar dissolved. Since different amounts of salt and sugar dissolved, students should recognize that this test might be useful in identifying the unknown. If the amount of the unknown left in the cup is about the same as the amount left behind by another crystal, then it’s reasonable to conclude that the unknown is that crystal.

4. **Introduce the term “solubility” and plan a solubility test.**

Distribute *Demonstration sheet 2a—Solubility is a characteristic property*. Explain that the ability of a substance to dissolve in water is a characteristic property called *solubility*. For example, sugar is a white substance that forms crystals and is more soluble than salt.

Ask students to think about how they might conduct a solubility test on salt, Epsom salt, MG, sugar, and the unknown. Have students work in groups to discuss their ideas and record a simple plan on the activity sheet.

5. **Discuss student plans and introduce the idea of how to measure equal amounts.**

Ask a few students to share their plans to dissolve each of the crystals in water. Ask students how each of the plans controls variables to make the test as fair as possible. When students bring up using equal amounts of crystals, ask them how they could measure equal amounts. Students may suggest using a volume measure like a teaspoon or weighing the crystals. Tell students that you will do another demonstration to help them decide how to measure equal amounts of the crystals. (*Demonstration 2b—Measuring equal amounts of crystals for the solubility test, p. 92.*)
Solubility is a characteristic property

Do some of the crystals dissolve more or less than others?

1. More salt was left in the bottom of the cup than sugar. What does this tell you about the “dissolve-ability” of salt compared to sugar?

_____________________________________________________________________
_____________________________________________________________________

Scientists use the word solubility when they are talking about the amount that a substance dissolves. Solubility is a characteristic property of a substance. Different substances are going to be more or less soluble than others.

This means that you could use a solubility test to notice differences in each of the crystals and to identify the unknown. If the amount of the unknown left in the cup is about the same as the amount left in a cup by another crystal, then it’s reasonable to conclude that the unknown is that crystal.

2. How could you conduct a solubility test to compare how well salt, Espom salt, sugar, MSG, and the unknown dissolve in water? Write a simple plan below.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

3. List the variables you would need to control.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
Demonstration 2b
Measuring equal amounts of crystals for the solubility test

What is the best way to measure equal amounts of crystals?

In Demonstration 2a, students saw that comparing the solubility of different substances requires testing equal amounts of each substance. In this demonstration students will see that to measure equal amounts, measuring by mass is better than measuring by volume.

Materials needed for the demonstration
Primary balance scale
2 Clear plastic cups
Zip-closing plastic bag, quart-size
Ball-shaped cereal

Notes about the materials
• Be sure you and the students wear properly fitting goggles.

Preparing materials
• Fill two clear plastic cups to the top with cereal balls. Place both filled cups on a simple balance to see whether the cereal in each cup weighs the same. If needed, adjust the amount of cereal until the cups balance.

Activity sheet
Copy Demonstration sheet 2b—Measuring equal amounts of crystals for the solubility test, p. 93, and distribute one per student when specified in the activity.

Assessment
An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.

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Demonstration 2b  
Measuring equal amounts of crystals for the solubility test

Question to investigate

What is the best way to measure equal amounts of crystals?

1. Show students two identical cups, each containing the same amount of cereal balls. 
   Hold the cups filled with cereal up so that students can see that both have about the same amount of cereal in them. Prove to your students that both contain the same amount of cereal by placing the cups on either end of a simple balance. Ask students how the height of the cereal in a cup will change if you smash the cereal balls from that cup. Students will probably suggest that the smashed cereal will not take up as much room in the cup.

2. Crush the cereal from one cup.
   Pour the cereal from one of the cups into a storage-grade, zip-closing plastic bag. Get as much air out as possible and seal the bag. Place it on the ground, and smash the contents thoroughly with your foot. Once the cereal is pulverized, open the bag, and pour the crushed cereal bits back into the cup.

3. Prove that the amount of cereal in each cup is the same.
   Hold both cups up and ask students which cup contains more cereal. Ask them if any cereal was added or removed from either cup. Point out that even though the crushed cereal takes up less space, it is still the same amount of matter (cereal) as was in the cup before it was crushed. Ask students how they could prove that these two cups actually contain the same amount of matter. They should suggest placing the cups on a balance scale as you did before. Do this so that students can see that the cups still balance.

   Expected results: The cups should balance on the scale.

4. Compare this example to large and small crystals.
   Tell students to imagine that the cereal balls are crystals. The large cereal balls represent large crystals and the crushed cereal represents small crystals. Ask students if each cup has the same amount of crystal in it. Students may be tempted to say that the cup with the small crystals has less crystal in it. Point out to students that the cups have the same amount of matter in them. Explain that the size and shape of the crystals may be different, but the balance shows that their mass is the same.

5. Conclude that, in order to measure equal amounts, it is better to weigh substances than to measure by using volume.
   Distribute Activity sheet 2b—Measuring equal amounts of crystals for the solubility test. Tell students that in the solubility test they will do, they will need to measure equal amounts of the five crystals. Ask students what they think would be the best way to measure equal amounts. After this demonstration, students should realize that weighing is better than measuring by volume. In order to make sure that all students understand the important concept demonstrated, have them answer the questions on the activity sheet.
Student activity sheet
Demonstration 2b

Measuring equal amounts of crystals for the solubility test

What is the best way to measure equal amounts of crystals?

1. Even though the mass of cereal in each cup is the same, after crushing the balls in one of the cups, the volume looks different. How do you know that the amount of cereal in each cup is actually the same?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

2. Using evidence from the demonstration, explain why it is best to weigh the crystals instead of using a volume measure like a teaspoon for your solubility test.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

3. Why would accidentally using different amounts of substances make the solubility test unfair?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Name: ______________________________
Activity 2.3
Solubility test

Can you identify the unknown crystal by the amount that dissolves in water?

In Demonstration 2a, students saw that more salt is left behind than sugar when both crystals are mixed with the same amount of water. Students can apply this same dissolving test to their known crystals and to the unknown. Since the unknown is chemically the same as one of the known crystals, it should dissolve similarly. By dissolving each of the crystals in the same amount of water and comparing the amount of crystal left behind, students will gain some information about the possible identity of the unknown.

Materials needed for each group
Salt in cup Masking tape 6 Small plastic cups, 3½-ounce
Epsom salt in cup Pen Plastic teaspoon
MSG (Accent®) in cup Ruler Hot tap water
Sugar in cup Permanent marker 10 Paper clips
Kosher salt in cup (unknown) 5 Clear plastic cups

Notes about the materials
• Be sure you and the students wear properly fitting goggles.
• Students should use care when handling hot tap water.
• Standard metal paper clips weigh about 0.4–0.5 grams each. Students should use 10 identical paper clips to measure 4 to 5 grams of each crystal. About 4 or 5 grams of each crystal is enough to observe differences in solubility.
• The labeled cups and the solutions made during this activity will be used again in Activity 2.4.
• Activity 2.4—Recrystallizing test should be done immediately after Activity 2.3—Solubility test.

Preparing materials
• Use the crystals in the source cups from Activities 2.1 and 2.2. If necessary add about 2 teaspoons of each crystal to its labeled cup.

Activity sheet
Copy Activity sheet 2.3—Solubility test, pp. 98–100, and distribute one per student when specified in the activity.

Assessment
An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.

Salt in cup
Epsom salt in cup
MSG (Accent®) in cup
Sugar in cup
Kosher salt in cup (unknown)
Masking tape
Pen
Ruler
Permanent marker
5 Clear plastic cups
6 Small plastic cups, 3½-ounce
Plastic teaspoon
Hot tap water
10 Paper clips
Activity 2.3  
Solubility test

Question to investigate

Can you identify the unknown crystal by the amount that dissolves in water?

1. Have students weigh equal amounts of the crystals.

The amounts of crystal and water used in this solubility test are specific and should be used because they give clear results. There are a variety of methods students could use to weigh equal amounts of each crystal. They could construct a balance themselves, like the one described below, or they could use any scale that can weigh 4–5 grams.

Procedure

1. Use your masking tape and pen to label five small cups salt, sugar, epsom salt, MSG, and unknown. Label five larger clear plastic cups in the same way. You should have two labeled cups for each type of crystal.

2. Tape the pencil down as shown. Roll two small pieces of tape so that the sticky side is out. Stick each piece of tape to the opposite end of the ruler. Place the small empty salt cup on one piece of tape so that the edge of the cup bottom is right at the end of the ruler. Place a small unlabeled cup on the other piece of tape in the same way.

3. Lay the ruler on the pencil so that it is as balanced as possible. Use a permanent marker to make a mark on the ruler at the point where it is balanced on the pencil. This is your balance point.

Note: Students may find it difficult to get the ruler to balance perfectly. Reassure them that if they get the ruler close to balancing, it will be accurate enough.
4. Carefully place 10 paper clips in the unlabeled cup. Slowly add salt to the salt cup until the cup with the paper clips just barely lifts from the table. Remove the salt cup from the ruler and set it aside.

5. Weigh the other four crystals in the same way so that you have equal amounts of all five crystals in their small labeled cups.

2. **Discuss the variables that need to be controlled in the solubility test.**

   Ask students how they might mix the crystals into water to compare how they dissolve. You could ask questions such as the following to bring attention to the variables in this test.
   - How many cups do we need?
   - Should the cups all have the same amount of water?
   - What else about the water should be the same? (same temperature)
   - What is a good way to mix the crystals into water in each cup?

3. **Have students dissolve the crystals in water.**

   The following procedure is also listed on Activity sheet 2.3—Solubility test. The amount of water used in the procedure is specific and should be used because it gives clear results. Swirling the crystals in water is a good way of mixing them to help them dissolve. Lead the class so that all groups pour their crystal samples into the water at the same time. Also tell students when to swirl the water and crystals and when to stop and observe. There will be three 20-second intervals.

   **Procedure**

   1. Place 1 teaspoon of hot tap water into each empty clear plastic cup.

   2. Match up each pair of cups so that each cup of crystal is near its corresponding cup of water. With the help of your lab partners, listen for your teacher’s instructions, and pour the weighed amount of each crystal into its cup of water at the same time.

   3. With the help of your lab partners, swirl each cup at the same time and in the same way for about 20 seconds and observe. Swirl again for 20 seconds and observe and then for 20 more seconds and make your final observations.
4. Slowly and carefully pour the solution from each clear plastic cup back into its small empty cup. Try not to let any undissolved crystal go into the small cup. Compare the amount of crystal remaining in each clear plastic cup.

Students should use their observations during the solubility test to help them answer the questions about the possible identity of the unknown on the activity sheet.

4. **Have students discuss their observations.**

Ask students questions such as the following:

- Do you have enough information to identify the unknown?
- Are there any crystals that you could rule out as probably not the unknown?
- What do you think is the identity of the unknown?
- What evidence do you have to support your conclusion?
- If someone in the class had a very different conclusion and had very different observations, what do you think may have led to these differences?

Students should mention possible errors in weighing the crystals, in measuring the amount of water used, the amount and type of stirring, or accidentally pouring the crystals into the wrong cups.

**Expected results:** Results may vary somewhat depending on the temperature of the water. However, Epsom salt and sugar should dissolve the most. MSG should appear to dissolve more than salt and the unknown. The salt and the unknown should appear to dissolve to a similar degree.

Based on their observations, students are most likely to eliminate Epsom salt and sugar as the possible identity of the unknown. They might conclude that the unknown is salt, but in some cases might think it could also be MSG. Since they may have some doubt, students will do a recrystallization test with the crystal solutions from this solubility test.

**Note:** *Activity 2.4—Recrystallization test* should be done immediately after the solubility test with the solutions made during this activity.
Solubility test

Build your own balance

Procedure
1. Use your masking tape and pen to label five small cups salt, Epsom salt, MSG, sugar, and unknown. Label five larger clear plastic cups in the same way. You should have two labeled cups for each type of crystal.

2. Tape the pencil down as shown. Roll two small pieces of tape so that the sticky side is out. Stick each piece of tape to the opposite end of the ruler. Place the small empty salt cup on one piece of tape so that the edge of the cup bottom is right at the end of the ruler. Place a small unlabeled cup on the other piece of tape in the same way.

3. Lay the ruler on the pencil so that it is as balanced as possible. Use a permanent marker to make a mark on the ruler at the point where it is balanced on the pencil. This is your balance point.

Don’t worry if you cannot get the ruler to balance perfectly. If you get the ruler close to balancing, it will be accurate enough.

4. Carefully place 10 paper clips in the unlabeled cup. Slowly add salt to the salt cup until the cup with the paper clips just barely lifts from the table. Remove the salt cup from the ruler and set it aside.

5. Weigh the other four crystals in the same way so that you have equal amounts of all five crystals in their small labeled cups.
Solubility test (continued)

Can you identify the unknown crystal by the amount that dissolves in water?

Use the procedure below to compare the solubilities of salt, Epsom salt, MSG, sugar, and the unknown.

Procedure
1. Place 1 teaspoon of hot tap water into each empty clear plastic cup.

2. Match up each pair of cups so that each cup of crystal is near its corresponding cup of water. With the help of your lab partners, listen for your teacher’s instructions, and pour the weighed amount of each crystal into its cup of water at the same time.

3. With the help of your lab partners, swirl each cup at the same time and in the same way as your teacher counts for 20 seconds. When your teacher tells you to stop, compare the amount of crystal left behind in each cup. Listen for your teacher’s instructions and swirl again for 20 seconds and observe. Swirl again for 20 seconds and make your final observations.

4. Slowly and carefully pour the solution from each clear plastic cup back into its small empty cup. Try not to let any undissolved crystal go into the small cup. Compare the amount of crystal remaining in each clear plastic cup.
Solubility test (continued)

Can you identify the unknown crystal by the amount that dissolves in water?

1. Draw your observations. Try to show the difference in the amount of crystal remaining in each cup.

Salt  Epsom salt  MSG  Sugar  Unknown

2. Based on the amount of crystal remaining in each cup, do you have enough information to identify the unknown?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

3. Which crystals are probably not the unknown? _____________________________
   Explain how your observations lead you to this conclusion.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

4. Based on what you saw in the appearance test, crushing test, and this solubility test, do you have enough information to identify the unknown? ____________________

   With the information you have so far, what might be the identity of the unknown?

_____________________________________________________________________
Activity 2.4
Recrystallization test

Can you identify the unknown crystal by the way it looks when it recrystallizes?

The way a substance dissolves in water is a characteristic property of that substance. Similarly, the way a substance “un-dissolves”, or recrystallizes, is also a characteristic property of the substance. The following recrystallization tests provide another clue that can help confirm the identity of the unknown. In this activity, students will allow each sample of crystal solution made in Activity 2.3 to recrystallize. The crystals that form appear different enough that students will be able to positively identify the unknown. Two different methods for recrystallization are provided in this activity.

24-Hour method
The 24-hour method may be preferable since the solutions are left overnight to recrystallize and show clear differences when students view them the next day.

Same-day method
If you need results within 1–3 hours, you may want to try the same-day method. Since the testing surface will be paper and characteristics of paper vary, this test is not as reliable as the 24-hour method. The absorbency of the papers affects the quality of the crystals and the ability to observe them on the surface of the paper. Test one sheet of paper according to the instructions on p. 103 before trying this method with your students.

Materials needed for each group

<table>
<thead>
<tr>
<th>24-Hour method</th>
<th>Same-day method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Labeled clear plastic cups</td>
<td>Crystal solutions from Activity 2.3</td>
</tr>
<tr>
<td>from Activity 2.3</td>
<td>Permanent marker</td>
</tr>
<tr>
<td>Crystal solutions from Activity 2.3</td>
<td>Cotton swabs</td>
</tr>
</tbody>
</table>

Notes about the materials

- Be sure you and the students wear properly fitting goggles.
- Activity 2.4—Recrystallizing test should be done immediately after Activity 2.3—Solubility test using the crystal solutions made during the activity.

Activity sheet

Copy either Activity sheet 2.4—Recrystallization test, 24-hour method, pp. 104–105, or Activity sheet 2.4—Recrystallization test, same-day method, pp. 106–107, and distribute one per student when specified in the activity.

Assessment

An assessment rubric for evaluating student progress during this activity is on pp. 108–109. For this formative assessment, check a box beside each aspect of the activity to indicate the level of student progress. Evaluate overall progress for the activity by circling either “Good”, “Satisfactory”, or “Needs Improvement”.

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Activity 2.4
Re crystallization test

Question to investigate

Can you identify the unknown crystal by the way it looks when it recrystallizes?

24-Hour method

1. Students will reuse the large clear plastic cups and solutions from Activity 2.3 according to the procedure below.

Procedure

1. Rinse each large clear plastic cup with water to remove any remaining crystal. Dry each with a paper towel.

2. Carefully pour the solution from each small cup into its corresponding large clear plastic cup.

3. Allow the solutions to sit overnight.

2. The next day, have students observe the crystals.

Distribute Activity sheet 2.4—Re crystallization test, p. 104–105. You may want to have students use a magnifying glass so that they can better see details of the crystals. Have students observe the crystals from the top and bottom of the cup and describe what they see in each cup.

Expected results: Salt and the unknown look very similar. Epsom salt, MSG, and sugar look different from each other and different from salt and the unknown. The sugar may not have recrystallized yet, but given more time it will form large clear crystals.

When students have completed the activity sheet, ask them questions like the following:

- What do you think is the identity of the unknown?
- Do you have enough information to be sure?

Students should be able to determine that the identity of the unknown is salt. Tell students that the unknown is coarse kosher salt. It is chemically the same as regular salt, but the process for making each is different and that is why they look different.
**Same-day method**

1. **Have students apply the solutions to the activity sheet.**

   Distribute *Activity sheet 2.4—Recrystallization test*, pp 106-107. Tell students that they will apply some of each solution to the circles on the activity sheet. When the water evaporates, crystals will re-form.

   **Procedure**

   1. Although the circles are already black, use a black permanent marker to completely cover each circle with a layer of marker.

   2. Dip a cotton swab into one of the solutions. Apply the solution in a circular motion to its labeled area on the activity sheet. Repeat until as much of the circle is covered with the solution as possible.

   3. Using clean cotton swabs, repeat Step 2 for the other four solutions. Set the paper aside and check it in about an hour. If not much crystal has formed; check it again in another hour.

   4. Compare the unknown to the other crystals.

2. **Have students discuss their observations.**

   Students can use a magnifying glass to better see details of the crystals. Ask students what they see on each circle.

   *Expected results*: Salt and the unknown look very similar. Epsom salt, MSG, and sugar look different from each other and different from salt and the unknown. The sugar may not have recrystallized yet.

   When students have completed the activity sheet, ask them questions like the following:

   - What do you think is the identity of the unknown?
   - Do you have enough information to be sure?

   Students should be able to determine that the identity of the unknown is salt. Tell students that the unknown is coarse kosher salt. It is chemically the same as regular salt, but the process for making each is different and that is why they look different.
Recrystallization test, 24-hour method

Can you identify the unknown crystal by the way it looks when it recrystallizes?

Procedure

1. Rinse each large clear plastic cup with water to remove any remaining crystal. Dry each with a paper towel.
2. Carefully pour the solution from each small cup into its corresponding large clear plastic cup.
3. Allow the solutions to sit overnight.
4. Use a magnifier to observe the crystals from the top and bottom of the cup. Compare the crystals in each cup.

1. What do you think is the identity of the unknown?

_____________________________________________________________________

2. What evidence do you have to support your conclusion?

_____________________________________________________________________

_____________________________________________________________________

Recrystallization in nature

Recrystallization doesn’t only happen in a cup. Stalactites and stalagmites in caves are another example of recrystallization. Stalactites form at the ceiling of the cave and point down. Stalagmites form on the floor of the cave directly beneath stalactites and point up.

Water that is slightly acidic seeps through tiny cracks in the ceiling of the cave and dissolves some of the limestone rock. If the drop of water hangs from the ceiling long enough, the water evaporates and the limestone recrystallizes. If this happens over and over again for hundreds of thousands of years, a stalactite is formed.

3. Why do you think stalagmites form directly underneath stalactites?

_____________________________________________________________________

_____________________________________________________________________
Salt and kosher salt are both made of sodium chloride. The reason the crystals look different has to do with the way they are processed. Regular salt and kosher salt are both made by allowing salt water to evaporate. But the solution used to make kosher salt is constantly raked while the water is evaporating. This interferes with the way the crystals would ordinarily develop, causing them to come together in an irregular way. In this super-magnified view of a piece of kosher salt, you can recognize the cubic shape you ordinarily see in a single crystal of table salt.

Photo courtesy of the Museum of Science, Boston.
Activity 2.4
Recrystallization test—same-day method

Can you identify the unknown crystal by the way it looks when it recrystallizes?

Procedure
1. Although the circles are already black, use a black permanent marker to completely cover each circle with a layer of marker.

2. Dip a cotton swab into one of the solutions. Apply the solution in a circular motion to its labeled area on the activity sheet. Repeat until as much of the circle is covered with water as possible.

3. Using clean swabs, repeat Step 2 for the other four solutions. Set the paper aside and check it in about an hour. If not much crystal has formed; check it again in another hour.

Compare the unknown to the other crystals

1. What do you think is the identity of the unknown? __________________________

2. What evidence do you have to support your conclusion? ___________________________________________________________________
Recrystallization in nature

Recrystallization doesn’t only happen on paper. Stalactites and stalagmites in caves are another example of recrystallization. Stalactites form at the ceiling of the cave and point down. Stalagmites form on the floor of the cave directly beneath stalactites and point up.

Water that is slightly acidic seeps through tiny cracks in the ceiling of the cave and dissolves some of the limestone rock. If the drop of water hangs from the ceiling long enough, the water evaporates and the limestone recrystallizes. If this happens over and over again for hundreds of thousands of years, a stalactite is formed.

3. Why do you think stalagmites form directly underneath stalactites?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Salt and kosher salt are both made of sodium chloride. The reason the crystals look different has to do with the way they are processed. Regular salt and kosher salt are both made by allowing salt water to evaporate. But the solution used to make kosher salt is constantly raked while the water is evaporating. This interferes with the way the crystals would ordinarily develop causing them to come together in an irregular way. In this super-magnified view of a piece of kosher salt, you can recognize the cubic shape you ordinarily see in a single crystal of table salt.

Photo courtesy of the Museum of Science, Boston.
Investigation 2—Physical properties and physical change in solids

Assessment rubric

How can you tell if crystals that look the same are really the same or different?

Activity 2.1—Curious Crystals
Can you identify the unknown crystal by comparing its appearance to other known crystals?

G S N
☐ ☐ ☐ Follows given procedures
☐ ☐ ☐ Describes characteristics of crystals with words and/or drawings
☐ ☐ ☐ Observes and describes similarities between crystals
☐ ☐ ☐ Determines whether or not there is enough information to identify the unknown
☐ ☐ ☐ Suggests tests that might help identify the unknown crystal

Circle one:  Good          Satisfactory          Needs Improvement

Activity 2.2—Crushing test
Can you identify the unknown crystal by crushing the different crystals and comparing them?

G S N
☐ ☐ ☐ Plans experiment with group
☐ ☐ ☐ Identifies and controls variables
☐ ☐ ☐ Conducts the experiment
☐ ☐ ☐ Determines whether or not there is enough information to identify the unknown

Circle one:  Good          Satisfactory          Needs Improvement

Demonstration 2a—Solubility is a characteristic property
Do some of the crystals dissolve more or less than others?

G S N
☐ ☐ ☐ Participates in discussion about how to best design a solubility test
☐ ☐ ☐ Compares the solubility of salt and sugar based on the demonstration
☐ ☐ ☐ Plans a fair solubility test
☐ ☐ ☐ Identifies variables that will need to be controlled

Circle one:  Good          Satisfactory          Needs Improvement

Demonstration 2b—Measuring equal amounts of crystals for the solubility test
What is the best way to measure equal amounts of crystals?

G S N
☐ ☐ ☐ Explains why the cups in the demonstration contained the same mass of cereal, even though the volumes appear different
☐ ☐ ☐ Explains why mass is better than volume when designing a fair test

Circle one:  Good          Satisfactory          Needs Improvement
Investigation 2—Physical properties and physical change in solids

Assessment rubric (continued)

Activity 2.3—Solubility test
Can you identify the unknown crystal by the amount that dissolves in water?

G S N

☑ ☑ ☑ Follows given procedure to weigh crystals
☑ ☑ ☑ Discusses the variables that need to be controlled in the solubility test
☑ ☑ ☑ Works with group to follow given procedure
☑ ☑ ☑ Considers the possible identity of the unknown
☑ ☑ ☑ Uses results from the appearance, crushing, and solubility tests to explain reasoning

Circle one:  Good  Satisfactory  Needs Improvement

Activity 2.4—Recrystallization test
Can you identify the unknown crystal by the way it looks when it recrystallizes?

G S N

☑ ☑ ☑ Follows given procedure
☑ ☑ ☑ Considers whether there is enough information to identify the unknown
☑ ☑ ☑ Uses evidence from recrystallization test to identify the unknown
☑ ☑ ☑ Extends observations to explain the formation of stalagmites in caves

Circle one:  Good  Satisfactory  Needs Improvement

To earn a “B”, a student must receive a “Good” in each category.

To earn an “A”, a student must also exhibit some of the following qualities throughout this investigation.

☑ Writes outstanding explanations
☑ Possesses a well-developed understanding of possible variables
☑ Participates well in class discussions
☑ Participates well in group work
☑ Uses scientific thinking
☑ Consistently exhibits exceptional thought and effort in tasks
☑ Other ____________________________
Teacher instructions

Review and apply

The following section contains activities, worksheets, and information that can serve as a summative assessment. Once students have completed the activities in Investigation 2, they will reflect on their learning, apply what they learned about experimental design to a new activity, and read about the importance of salt. An optional reading explains, on the molecular level, what happens when different crystals dissolve and recrystallize. Answers to the worksheet questions for this section are available at www.inquiryinaction.org

Let’s review

1. Review with students what they learned in the crystals investigation.

   Distribute Review and apply: Let’s Review, p. 112, and give students an opportunity to respond to the prompts on their own. Once students think about and write their ideas, discuss what students learned about controlling variables in the solubility and recrystallization tests.

Science in action!

2. Have each student conduct the appearance, crushing, solubility, and recrystallization tests to compare sodium chloride to potassium chloride.

   Show students containers of salt and salt substitute made from potassium chloride. Tell them that the salt that is often added to their food has a chemical name—sodium chloride. Salt substitute is chemically different, it’s potassium chloride. Explain that some people need to limit the amount of sodium in their diet, so are encouraged to use potassium chloride instead. Challenge students to conduct all of the tests they conducted on the crystals during this investigation on both the sodium chloride and the potassium chloride. This activity and the corresponding Review and apply worksheet can serve as a summative assessment, evaluating the students’ ability to control variables and conduct all of the tests introduced in this investigation.

   Distribute Review and apply: Science in action!, pp. 113–114. This activity may be conducted either at home or in class.

3. Have each student design and conduct a test to compare how sodium chloride and potassium chloride solutions absorb into a surface.

   After students complete their appearance, crushing, solubility, and recrystallization tests, they will design an absorption test. First, students will need to make solutions using potassium chloride and sodium chloride. Variables should be controlled when making the solutions. Students should use the same amount and temperature of water and the same mass of sodium chloride and potassium chloride and should stir for the same length of time. Students will also need an absorbing surface, like a brown paper towel or a coffee filter. Students may choose to place a small amount of each liquid on the paper or to dip strips of paper into the solutions. Either way the solutions will absorb into the paper at different speeds.
Distribute activity sheet *Review and apply: Science in action! continued*, p. 115. This activity may be conducted either at home or in class. Make a variety of materials available. You might supply water, clear cups, brown paper towels or coffee filters, droppers, or some other suitable materials. Also give each group about 1 teaspoon each of sodium chloride (table salt) and potassium chloride (Nu-Salt®).

This activity and the corresponding activity sheet can serve as a summative assessment, evaluating students’ skills in designing a fair test, identifying and controlling variables, and recording observations.

4. **When students have completed their experiments, compare experimental designs and observations.**

Have students join small groups and describe their experiments and their results. With the whole class, ask students to describe any similarities or differences between their experiment and someone else’s. If the design of the experiment was similar, did students have similar results? Did students notice a difference in the way potassium chloride and sodium chloride absorbed into a particular surface?

**Think about it**

5. **Have students read about salt and then answer questions.**

Distribute *Review and apply: Think about it*, pp. 116–119. Tell students that salt (sodium chloride) is pretty inexpensive and is available in just about any store that sells food. But once it was very expensive and hard to come by. Students will read about salt, find out why people and animals need it, learn how it’s used, and discover where it comes from. Then they will answer questions about the reading.

For additional information about salt, go to [www.inquiryinaction.org](http://www.inquiryinaction.org)

**What’s going on here? (optional)**

**Molecular explanations for students**

If you think the content is developmentally appropriate for your students, have them read about dissolving and recrystallization on the molecular level and answer questions about the reading.

Distribute *Review and apply: What’s going on here?*, pp. 120–124. This reading describes the structure of the water molecule and explains how this structure helps it to dissolve sugar, salt, and the other ionic substances used in this investigation. It also explains the process of recrystallization.

This type of molecular explanation is not suitable for all students. It is intended for students who have prior experience learning about the structure of atoms and molecules. This content is included for teachers and students who would like to be able to explain common observations on the molecular level. Discuss the process of dissolving and recrystallization with students based on the reading.

Material to support this reading can be found at [www.inquiryinaction.org](http://www.inquiryinaction.org)
Let's review

At the beginning of this investigation a student noticed that salt and sugar look pretty similar. She decided to look at them and at Epsom salt and MSG with a magnifier. You did the same thing and did other tests to discover the identity of an unknown crystal.

1. One of the tests you did to learn about and compare the crystals was a dissolving test. Describe how you conducted the dissolving test. Explain what you did to control variables that might affect dissolving such as amount of water, temperature of water, amount of swirling, etc.

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2. You also did a recrystallization test. Explain what you did to control the variables in this test.

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_____________________________________________________________________
Science in action!

How does potassium chloride compare to sodium chloride?

When we think of salt, we usually think of the salt we sprinkle on our french fries, eggs, or other food. This salt is sodium chloride. For a long time, sodium chloride was the only salt you could buy to use on your food. But people with high blood pressure or certain other medical conditions are supposed to limit the amount of sodium in their diet. So food scientists tried a different kind of salt called *potassium chloride* to see if it could be used instead of sodium chloride. These days, you can find potassium chloride in most grocery stores where it is sold as a salt substitute.

In order to compare potassium chloride to sodium chloride, you will need to conduct several tests on each of the crystals. First, conduct the appearance, crushing, solubility, and recrystallization tests on potassium chloride and sodium chloride. Then explain your test and record your observations using the chart on the next page.
### Compare potassium chloride to sodium chloride

<table>
<thead>
<tr>
<th>Test</th>
<th>Recrystallization</th>
<th>Solubility</th>
<th>Crushing</th>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>How did you conduct the test?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What did you observe?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Review and apply worksheet**

**Name: _____________________________**
Science in action! (continued)

How does potassium chloride compare to sodium chloride?

Design your own absorption test

The way a potassium chloride or a sodium chloride solution absorbs into a particular surface might show some interesting similarities or differences. Develop an absorption test of your own. You might use water, clear cups, food coloring, paper towels, coffee filters, droppers, or some other materials available in your classroom or home.

1. Describe what your absorption test might be like.

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2. How will you control variables in your absorption test?

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_____________________________________________________________________
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Conduct your absorption test

Record your observations

<table>
<thead>
<tr>
<th>Potassium chloride</th>
<th>Sodium chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Think about it

Salt

Salt (sodium chloride) is a lot more interesting than we give it credit for. Did you know that salt wasn’t always so easy to get and used to be very valuable? In fact in ancient Rome, soldiers used to be paid with an amount of salt called a *salarium*. This is where the word “salary” comes from. Salt was considered so precious that kings and queens had elaborate silver containers, called *salt cellars*, specially made to hold salt at the table. In fact, the expression “salt of the earth” describes a particularly kind and good person.

Who needs salt?

Humans and other animals need salt. Animals in the wild who find a salt deposit will travel back to it over and over again to lick up some salt. In the past, animals have created paths that people also followed to get the salt. Some of these paths eventually were made into roads, which people used to trade and sell salt. Sometimes whole towns would start because of these salt deposits and roads.

The body requires a certain amount of salt to function properly. Salt plays an important role in helping to maintain the volume of fluid in the blood stream, cells, and tissues. The sodium from salt also plays an important role in nerve function. The digestive, circulatory, and excretory systems help balance the amount of salt taken in and the amount absorbed and excreted. Sometimes this balance can be thrown off by extreme sweating or by not taking in enough fluids.

What happens when there is too much salt?

Some animals have special ways to balance the salt in their bodies. Salt water fish take in salty ocean water but need to get rid of the extra salt in order to survive. They excrete the extra salt in salty urine and through specialized cells in their gills. Freshwater fish have the opposite problem. They take in a lot of water but not much salt. With their kidneys, they excrete large quantities of dilute urine and take in salt through special salt-absorbing cells in their gills.
Sometimes, other animals that live near salt water take in too much salt and it needs to be removed from the body. Sea birds that eat a diet high in salt or drink salt water have large areas near their eyes called *salt glands*. These glands remove the extra salt by secreting a solution through the nose that is very high in salt and low in water. Because these glands are not fully developed in the young, adult birds will sometimes dunk food into freshwater before giving it to their babies.

Reptiles like sea turtles also take in a great deal of salt when they eat and drink. They have salt glands in their eye sockets which allow them to excrete leftover salt. The amount of salt in their tears can be twice as much as found in sea water. When female turtles nest to have babies, it looks like they are crying. Actually, they are excreting salt through their eye glands.

**Uses for salt**
As you probably know, salt isn’t just for making food taste better. One of its main uses in history was as a preservative. Meat and fish were treated with salt, which made it harder for bacteria to live and grow on the food. This allowed food to be transported over greater distances and to last longer while being stored. Salt is also used for purposes that have nothing to do with food. It is used in making soap and detergent, dying fabric, making paper, and in many other products and processes. Thousands of tons of salt are used to make roads safer for driving when there is snow and ice in the winter.

**Where does salt come from?**
There are two huge sources of salt on Earth. One is the salt that is dissolved in oceans and seas. The other is deposits of solid rock salt called *halite* which is under the earth’s surface. To get salt from ocean and sea water, the water is placed in large open pools and allowed to evaporate. This allows the sodium ions and the chloride ions dissolved in the water to recrystallize to form salt crystals.

There are two different methods for getting salt from beneath the earth. One technique is to drill down into a salt deposit and pump in large amounts of water to dissolve some of the salt. This salty water is then pumped up to the surface and allowed to evaporate, allowing the dissolved salt to recrystallize.

The other method is like underground mining where long mine shafts and tunnels are built to get down into the salt deposit. Machinery is used to blast, scrape, and dig the solid salt out of the ground. This salt is then sent up to the surface where it is crushed and processed.
Think about it (continued)

1. The reading suggests that salt deposits could have caused entire towns to be built. This is because…
   a. Where there is salt, there is water.
   b. Where there is salt, it is easier to grow crops.
   c. Animals like salt.
   d. Salt was very useful and valuable.

2. In history, salt has been used as a preservative. Re-read the “Uses for salt” section. What is the main reason for using a preservative?
   e. Makes food taste better
   f. Makes it harder for bacteria to live and grow
   g. To help make roads safer in winter
   h. To make soap and detergent

3. Salt is found dissolved in the oceans. In this sentence, what does the word “dissolve” mean?
   a. Water and salt are completely mixed, making salt water.
   b. Salt is found on the shore line.
   c. Salt is found in the ocean.
   d. Salt is also found in the body systems, including the digestive system.

4. What is the most likely reason that the author included the information about salt?
   a. To tell readers how much salt should be used on their food
   b. To explain to readers where they can find salt
   c. To teach readers about the importance of salt
   d. To encourage readers to put more salt on their foods

5. There are two places we can find salt on the earth. The type of salt that is found in solid rock is called…
   a. halite.
   b. halitosis.
   c. heme.
   d. Rockis saltis.

6. According to the details in the passage, what do sea turtles do to eliminate extra salt from their bodies?
   a. They remove the salt through their salt gills.
   b. They remove the salt through their tears.
   c. They remove the salt through their nose.
   d. They leave the extra salt in their bodies.
Think about it (continued)

7. People like the taste of salt, but we also need to have a certain amount of it in our bodies to keep us healthy. What is one of the roles of sodium in our bodies?
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

8. Animals that live in salt water need to get rid of excess salt. What is one way they do this?
_____________________________________________________________________

9. Salt makes food taste better. Name at least two other uses for salt.
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_____________________________________________________________________
_____________________________________________________________________

10. What are the two main sources of salt on Earth?
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_____________________________________________________________________
What’s going on here?

In this investigation, you saw that the amount of a substance that dissolves in water is different for different substances. You can begin to understand why this is by looking at both water and the substances being dissolved on the molecular level.

Dissolving
The first thing to understand about dissolving is that you have to look at the liquid doing the dissolving (solvent) as well as the substance being dissolved (solute). Dissolving depends on the interaction between the molecules of the solvent and the molecules of the solute.

Since you used water to dissolve the different substances and since dissolving occurs on the molecular level, you need to first look at the molecular structure of water.

Water molecules
A water molecule is made of two hydrogen atoms bonded to one oxygen atom. All atoms, including hydrogen and oxygen, have one or more protons in the center, or nucleus, of the atom. Atoms also have electrons that move around the nucleus. Protons have a positive electric charge, and electrons have a negative electric charge. An atom has the same number of electrons as it has protons.

Because of the characteristics of oxygen and hydrogen and how they are bonded together in the water molecule, there is a slight positive charge near the hydrogen atoms and a slight negative charge near the oxygen atom.

The smaller illustration to the right shows that the molecules in liquid water associate very closely with one another. The larger illustration shows how the water molecules tend to orient themselves according to their opposite charges. Notice how the positive area of one water molecule is attracted to the negative area of another.
Salt is made from positive and negative ions

Regular table salt is called sodium chloride. Its chemical formula is NaCl. Na stands for sodium and Cl stands for chlorine. When the sodium atom and the chlorine atom react, the sodium ends up with a positive charge and the chlorine ends up with negative charge. The positive sodium and the negative chloride are called ions. Because positive and negative attract, the sodium (Na\(^+\)) and chloride (Cl\(^-\)) ions attract each other and bond together. This is what keeps the sodium and chloride ions together to make a piece of salt.

This illustration is a model of a salt crystal drawn to give you a basic idea of what a salt crystal looks like. However, you should know that there are far more ions in a single salt crystal than this picture shows. The approximate number of sodium (Na\(^+\)) and chloride (Cl\(^-\)) ions in a typical crystal of ordinary table salt is actually around 1 million trillion of each.

How water dissolves salt

When salt is placed in water, the positive and negative ends of the water molecules are attracted to the negative chloride and positive sodium ions. When the attraction that the water molecules and an ion have for each other overcomes the attraction that the ion has for the other ions in the salt, that ion is pulled away and dissolves. So when water dissolves salt, it pulls away individual sodium and chloride ions.

Water can dissolve many substances made from ions

MSG and Epsom salt are also made of ions with a positive and negative charge. The ions that make up these different substances all have a different size, weight, strength of attraction, and overall structure. Because of this, they pack together differently to form their crystal shape. When water molecules interact with these substances, all these differences make it either easier or harder for the water molecules to pull the ions away and dissolve them. That’s why these substances dissolve to different extents and why you see some differences in how much is left undissolved of each substance.
**Dissolving sugar**

The kind of sugar you used in the activities is called *sucrose*. The chemical formula for sucrose is $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. In the sucrose molecule, there are many positive and negative areas. Sucrose molecules are attracted to other sucrose molecules and line up next to each other because of the attraction of opposite charges. This is what keeps sucrose molecules together in a piece of sugar.

When sucrose is placed in water, the positive and negative ends of the water molecules attract the negative and positive parts of the sucrose molecule. When the attractions that the water molecules have for the sucrose molecule become stronger than the attractions the sucrose molecule has for the other sucrose molecules, the sucrose molecule is pulled away and surrounded by water molecules. At that point it is *dissolved*. So, when water dissolves sucrose, entire sucrose molecules are pulled away from each other. But, when water dissolves salt, Epsom salt, or MSG, individual ions are separated from each other.
Recrystallizing
Another test you did to identify the unknown was the recrystallization test. You saw that as the water evaporated, some of the original substances recrystallized. You also saw that the different substances looked different when they recrystallized.

When the different substances dissolve, their ions or molecules are surrounded by water. This makes it hard for them to come together to begin to form a crystal. But as the water evaporates, there are fewer water molecules surrounding the ions or molecules. This makes it easier for them to come together and bond according to their positive and negative charges, or to recrystallize.

Once the solutions have evaporated, the resulting crystals look different from one another. This is because they are made of different ions with different structures and sizes that bond together in different arrangements. Both the unknown (coarse kosher salt) and the table salt look alike when they recrystallize because they are both sodium chloride.
What’s going on here? (continued)

1. Explain why water is able to dissolve salt (sodium chloride).

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2. Explain why the amount of salt and kosher salt that dissolved was so similar.

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3. Why do you think the salt and kosher salt looked similar when they recrystallized but looked different from the other substances?

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Cool factoid

In the Think about it section, you read that salt is a good preservative for food. Well it’s also a good preservative of people. Ancient Egyptians used sodium chloride and other types of salt to make a paste for preparing mummies. Also, well-preserved bodies of people who lived over 2,000 years ago have been found in salt deposits in different parts of the world.