

Separating a Soluble and an Insoluble Substance

Inquiries 2
Periods 2

CONCEPTS

A solid can be recovered from a solution by evaporating the solvent.

Insoluble substances will not pass through a fine filter.

Solutions will pass through a filter.

Knowledge of the properties of substances can be used to separate substances in a mixture.

STUDENT OBJECTIVES

Describe and discuss the formation of a solid from its evaporated solution.

Redissolve the solid from an evaporated solution.

Filter mixtures.

Separate a mixture of a soluble and an insoluble solid.

Design and conduct an inquiry to obtain a clean sample of salt from crushed rock salt.

OVERVIEW

In this lesson, students apply their knowledge of the properties of solutions, solubility, and phase change to the separation of a mixture containing a soluble and an insoluble substance. They start by examining crystals obtained from the copper(II) sulfate solution from Lesson 12. They discuss what the crystals are and how they were left behind when the water in the container evaporated. In Inquiry 15.1, they use the reconstituted solution to compare how a solution and an insoluble substance behave when poured onto filter paper. In Inquiry 15.2, students are challenged with obtaining a sample of clean salt from crushed rock salt.

BACKGROUND

In previous inquiries, students determined whether some substances were soluble or insoluble, and they became familiar with some of the properties of solutions. In this lesson, they use this knowledge to focus on two separation techniques that relate to solubility: filtration and evaporation. In “Getting Started,” students investigate the recovery of a solid from a solution by the evaporation of the solvent. They examine the container of copper(II) sulfate solution (which is now evaporated) from Lesson 12. A small quantity of deep blue crystals of copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) will be present in the container. The crystals may be larger than those used to make the original solution, but they will be the same shape. Comparing the approximate mass of the crystals with that of the crystals originally used to make the solution and then redissolving these crystals should reinforce the following concepts from previous

lessons: Solutes are present in solutions, and their mass is conserved. Students should conclude that evaporation can be used to recover solids from solutions.

In Inquiry 15.1, students learn about filtration. Most students will already know about filtration, if not in science, then through the use of sieves or coffeemakers. The inquiry has two functions: to teach students how to use the apparatus correctly and to allow them to discover that one property of solutions, as opposed to other mixtures, is that both the solute and the solvent can pass through filter paper.

In Inquiry 15.2, students apply their knowledge of solutions and use the skills they learned in Inquiry 15.1 to remove insoluble solids from rock salt. Rock salt, or halite, occurs naturally, usually in underground beds created from ancient surface deposits that formed when enclosed saline waters evaporated (see “Separating Solutions and the Salty Sea” in the Student Guide, pages 128–129). Sediments later buried these salt deposits. The resulting salt beds are often distorted by tectonic forces, which cause them to form into domelike subterranean structures called salt domes.

Salt is extracted from salt domes either directly, by “room-and-pillar” mining, or by making a solution from the deposit and water. In the United States, salt is usually extracted using the room-and-pillar method, in which rock salt is blasted, removed by machine, crushed, and taken to the surface, where it is screened and packed. In making a solution, hot water is forced into the deposit and returns to the surface as a saturated solution of brine. The water is then evaporated to obtain the salt.

Salt is a vital raw material for many chemical processes, including the manufacture of sodium carbonate (used in glassmaking), sodium hydroxide (used to make soap, paper, and textiles), and chlorine. Another major use of rock salt is in removing ice from roads.

The color of rock salt depends on its source. Iron compounds and other impurities sometimes give rock salt a brown color, but it is

generally white with visible mineral impurities. The composition of rock salt varies. Most of its soluble component is sodium chloride, but it can contain a diverse collection of soluble solids (the most common is potassium chloride, or sylvite). If the rock salt used in this lesson is mostly white in color, you may wish to make the challenge more difficult by contaminating it further with sand.

The soluble component of rock salt can be separated out by using two slightly different approaches. In both, water is added to a beaker that contains rock salt to dissolve the soluble component of the mixture. In the first method, the insoluble component is given time to sink to the bottom of the beaker and then the solution (or **supernatant**) is poured off, a process known as decanting. In the second method, the mixture is filtered, insoluble residue remains on the filter, and the solution is collected. In both methods, the solution is evaporated. Slow evaporation at room temperature is adequate for this inquiry, although students should discuss how the volume of solvent affects evaporation time. If you have evaporating dishes (they are not supplied in the kit), you could heat the solution to speed evaporation.

Student Misconceptions

Students often associate filtration with the purification of water. Some students will predict that filtration will remove the solute from a solution and expect that the copper(II) sulfate solution will lose its blue color when passed through the filter. This misconception is reinforced by the widespread use of water filters that “filter” clear water. Although these devices do remove small amounts of suspended solids and microorganisms by direct filtration, any soluble contaminants, which are often the cause of unpleasant taste or odor, are usually removed by activated carbon. Filter papers do not remove the solute from a solution; they simply separate the insoluble component from the soluble component (plus the solvent) of the mixture.

MATERIALS FOR LESSON 15**For the teacher**

- 1 pair of safety goggles
- 1 container labeled “Waste Copper(II) Sulfate Solution”
- 1 container labeled “Waste Zinc Oxide”
- 1 filter paper

For each student

- 1 copy of Student Sheet 15.1: Filtering a Solution
- 1 copy of Student Sheet 15.2: Cleaning Rock Salt
- 1 pair of safety goggles

For each group of 4 students

- Plastic container of copper(II) sulfate from Lesson 12
- 1 plastic container
- 1 labeled jar containing rock salt
- 1 labeled jar containing zinc oxide
- 2 filter funnels
- 2 100-mL graduated cylinders
- 6 filter papers
- 2 labels
- 2 lab scoops
- 2 magnifying loupes
- 4 large test tubes
- 2 test tube racks
- 2 250-mL beakers
- 2 teaspoons

PREPARATION

1. Make one copy of Student Sheet 15.1: Filtering a Solution and one copy of Student Sheet 15.2: Cleaning Rock Salt for each student.
2. Make sure that the plastic containers of copper(II) sulfate solution from Lesson 12 are available and that the water has evaporated from them.
3. Label jars of rock salt and zinc oxide.
4. Label one container “Waste Copper(II) Sulfate Solution” and another “Waste Zinc Oxide.”

SAFETY TIP

Check with your environmental health coordinator regarding local regulations for disposing of copper(II) sulfate and zinc oxide.

Getting Started

1. Have one member of each group collect a tote tray containing the materials. Another should collect the group’s labeled container of copper(II) sulfate solution from Lesson 12.

SAFETY TIP

Make sure students wear safety goggles during the entire lesson.

2. Have students follow Steps 2 and 3 of “Getting Started” in the Student Guide.
3. Ask students to describe their observations. Look for answers mentioning the color and shape of the crystals.

4. Ask students what the substance is. How did it get there? What happened to the water? Encourage correct use of scientific terms related to solutions and phase change.
5. Discuss how the rate of evaporation of the solvent could be increased (by heating, increasing the surface area, or increasing airflow over the surface of the solution). Ask how altering the amount of solvent (water) in the solution could change the amount of time it would take to obtain crystals from the copper(II) sulfate solution. (Dissolving the solute in the least possible amount of solvent greatly reduces evaporation time.)
6. Ask students what would happen if they added 25 mL of water to the container of crystals. They should all predict that the crystals will dissolve to form a solution of copper(II) sulfate.
7. Have students test their predictions by adding 25 mL of water to their containers. Have them stir the solution with a teaspoon to speed up dissolving. Review the properties of a solution by asking the following questions:

A. What happens after you add 25 mL of water to the blue crystals?

B. What are the properties of the mixture?

C. What do you think you have made?

8. Students should divide the solution in the container and the apparatus in the tote tray equally between the two pairs within their group.

Inquiry 15.1

Filtering a Solution

PROCEDURE

1. Show students how to fold the filter paper and insert it into a filter funnel.
2. Have students follow Step 1 of Inquiry 15.1 in the Student Guide.
3. In Table 1 on Student Sheet 15.1, have students write their prediction of what will happen when the copper(II) sulfate solution is poured into the filter funnel.
4. Students should assemble their apparatus as described in Step 3 of Inquiry 15.1 in the Student Guide and test their prediction. They should record their result in Table 1 on the student sheet.
5. Have students repeat the procedure with zinc oxide and water. They should record their predictions and results in Table 1.
6. Have students discuss their results with their lab partners.
7. Conduct a class discussion on students' results. Which property of solutions have they discovered? Discuss the concept that filters do not remove solutes from solutions but that they do remove insoluble components of a mixture, including a liquid.
8. Make sure one student from each pair disposes of the copper(II) sulfate solution in the waste container provided. Students should place used filter papers in the trash can. They should rinse the apparatus and return it to the tote tray.

Inquiry 15.2

Cleaning Rock Salt

PROCEDURE

1. Explain that rock salt is an impure form of salt obtained by mining salt deposits. Refer to the photograph of salt being mined on SG page 126.
2. Have students examine a sample of the rock salt by doing Step 1 in the Student Guide.
3. Ask students to describe the rock salt. They should write their descriptions on Student Sheet 15.2.
4. Have them discuss the following questions with their partners:
 - A. *Would you want to eat this sample?*
 - B. *Do you think it is pure?*
 - C. *What do you think the contaminants could be?* (Focus on insoluble minerals or rock fragments.)
5. Have each pair discuss how they could use the apparatus to obtain only the soluble component of the sample. Students should answer the questions in Steps 2 and 3 on Student Sheet 15.2, and each pair should agree on a procedure. Students should write their procedure on the student sheet.
6. Ask pairs of students about their procedural designs, but do not suggest a “correct” procedure.

7. Have each pair follow their own procedure to purify the salt. Circulate among the pairs, monitoring their progress. If students identify a problem with the procedure, ask them questions that will help them make appropriate modifications.

REFLECTIONS

1. Ask some students to outline their procedures and the problems they encountered.
2. Explain to students that because a clean sample of salt cannot be obtained until the water has evaporated from the solution, they will revisit the salt solutions in a later lesson. (Which lesson that will be depends on the length of time it takes for the water to evaporate completely.)
3. Have students read “Separating Solids From Liquids” on SG page 127.
4. When the water completely evaporates, spend about 10 minutes discussing the quality of the salt obtained by students (or reasons why they did not obtain any) and relate their results to the procedure they used.

HOMEWORK

Have students read “Separating Solutions and the Salty Sea” in the Student Guide and answer the accompanying questions.

EXTENSIONS

■ Science

1. If your local curriculum requires particulate theory to be taught at this level, you may wish to outline how particle size relates to filtration. This concept can easily be modeled using beads of different diameters and sieves of different mesh sizes.

■ Science

2. Filtering is one of the processes used in the treatment of sewage. Have students investigate sewage treatment and discover how different types of contaminants are removed from sewage.

■ Science

3. Have students define “filter feeding” and write in detail about one filter feeder.

■ Science

4. Have students conduct Internet research on the process of reverse osmosis.

■ Social Studies

5. Salt has always played an important role in world trade. Have students use Internet resources to investigate the history of salt extraction and trading.

■ Language Arts

6. Salt is often referred to in proverbs and quotations. Have students find out the meaning of the following examples:

- The salt of the earth
- With a grain of salt
- You will find how salt is the taste of another’s bread, and how hard is the way up and down another’s stairs

Have students investigate other sayings that refer to salt.

ASSESSMENT

1. Answers to questions in “Getting Started” can provide information on students’ understanding of the concepts of the conservation of solute mass during dissolving and the subsequent evaporation of the solvent.
2. Student procedures in Inquiry 15.2 provide an excellent opportunity to assess comprehension of concepts relating to solutions and their application using skills practiced in this and previous lessons. Focus on the correct terminology (such as soluble and insoluble, dissolve, solution, filter, and evaporate), application of knowledge of dissolving (using minimal quantities of solvent and recognizing when all the salt is dissolved), and separation (filtration/decanting and evaporation).

Name: _____

Class: _____ Date: _____

Student Sheet 15.1 Filtering a Solution

Directions Write your predictions and results in Table 1

Table 1 Results of Inquiry 15.1

Mixture	Prediction	Result
Copper(II) sulfate and water		
Zinc oxide and water		

Name:

Class: _____ Date:

Student Sheet 15.2 Cleaning Rock Salt

1. Describe your sample of rock salt.
2. What are you trying to do?
3. What materials will you use?
4. Write out the steps of your procedure. You may also use labeled illustrations.