Companion Lessons

Lesson 6: Mixtures, Properties, and Separation

Overview

This hands-on activity builds on and reinforces students' understanding of substances, properties, and chemical reactions. In the first of two class periods, students are challenged to find ways to use the properties of substances to separate a mixture. The teacher demonstrates combining four substances. The substances do not appear to change properties, so if no chemical reaction occurred, it should be possible to separate the mixture. To confirm that a reaction did not occur, students are challenged to design a method for separating the substances. They explore different separation methods and a variety of materials. Each group shares their results, followed by some additional testing to arrive at the best technique. A concluding discussion emphasizes how properties of materials can be used to separate mixtures. To prepare for the second day, the class discusses and investigates a sugar-water mixture. A day or two later (giving the water time to evaporate), students read, annotate, and discuss a short article that focuses on mixtures at the atomic scale. Students apply ideas from the article to both the first-day mixture and to the sugar-water mixture. Finally, students apply their new understanding to questions about a chemical spill in the water supply. The purpose of this lesson is to reinforce concepts about substances and properties and to introduce concepts about mixtures and how to separate them.

Recommended Placement: *Chemical Reactions*, after Lesson 2.3, 2.4, or 2.5
Suggested Time Frame: two 45-minute class periods

Materials & Preparation

Materials

For the class

- iron filings
- paraffin flakes
- sand
- sugar
- 24 small plastic bags
- 1 measuring spoon, tablespoon**
- 1 measuring spoon, teaspoon**
- water*
- masking tape*
- pitcher or other container for mixing sugar water*
- large spoon for stirring sugar water*
- plastic cup (9 oz) with water

For Each Group of Four Students

- 1 tray*
- 1 small plastic bag with iron-sand-paraffin-sugar mixture
- 1 magnet
- 5 plastic cups, 9 oz
- 1 small mesh strainer
- 1 plastic straw
- 2 paper coffee filters
- 1 plastic spoon
- 2 binder clips
- 1 plastic dropper bottle
- 1 small, red, plastic plate

For Each Student

- student booklet, pages S28–S34
  - “This Is Not an Oxygen Tank” article
  - Investigating Mixtures: Parts 1–4

*teacher provided
**from the *Chemical Reactions* kit

Preparation

1. **Prepare four plastic bags, each with one substance.** Measure 1 tablespoon of sand into a bag, 1 tablespoon of paraffin flakes into a second bag, 1 tablespoon of iron filings into a third bag, and 1 tablespoon of sugar into a fourth bag.
2. **Prepare bags with a mixture.** For each group of four students, prepare two small bags. In each bag, measure and add 1 teaspoon of sand, paraffin flakes, iron filings, and sugar. Mix well. Alternatively, make a large batch of the mixture with equal parts of the four substances and then measure 4 teaspoons into each bag.
3. **Preview the short article “This Is Not an Oxygen Tank.”** See Step 20 of the Instructional Guide.
4. **Identify a water source.** If you don’t have a sink in the classroom, fill one or more pitchers or other containers

Preparation (continued)

with water and place them where students can easily access them. Alternatively, you could add water to one cup for each group ahead of time.

5. **Prepare the trays.** Place a magnet, five small plastic cups, one small mesh strainer, one plastic straw, two paper coffee filters, one plastic spoon, and two binder clips on a tray for each group of four students.
6. **Prepare dropper bottles of sugar water.** In a pitcher or other container, make a sugar-water mixture. Mix ½ liter (about 2 cups) of water with 2 tablespoons of sugar and stir until the sugar is dissolved. Pour about 50 mL of this mixture into each dropper bottle (one for each group of four students).
7. **Prepare for teacher sugar-water demonstration.** Set aside 1 tablespoon of sugar, 1 plastic cup with water (½ full), and 1 plastic spoon. As instructed in Step 14 of the Instructional Guide, you will dissolve the sugar in water.
8. **Locate and review rubrics.** Review the Rubrics for Assessing Students' Understanding of Mixtures in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they apply ideas and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students' developing facility with Crosscutting Concepts as well as their understanding of Disciplinary Core Ideas.
9. **Plan for when you will resume this lesson after a break of 1–2 days.** Begin at Step 19 of the Instructional Guide.
10. **Immediately before the lesson, have on hand the following materials:**
    - student booklet pages
    - trays of materials
    - bags of individual substances
    - bags of iron-sand-parraffin-sugar mixture
    - dropper bottles with sugar water
    - plastic plates
    - materials for teacher sugar-water demonstration

Science Background

A substance is any matter made of the same atom or group of atoms that repeats over and over to form the entire sample of matter. Examples of substances are iron, water, carbon dioxide, salt, and sugar. Properties are observable qualities of a substance such as its color, odor, density, and boiling point. All matter is either a substance (some texts use the term *pure substance*) or a mixture of substances. A mixture is matter that is made of more than one substance. Most matter encountered in everyday life is a mixture of substances. It is often possible to separate a mixture into its constituent substances by physical means, using processes that affect the substances in the mixture differently, due to their different properties. For example, distillation separates a mixture by using the different boiling points of the substances in the mixture. The mixture is slowly heated until the substance with the lowest boiling point turns into a gas. This gas is then separated out and cooled to condense back to a liquid. Other physical separation methods include filtration (e.g., if one substance in a mixture is a solid and another is a liquid), density separation (if one substance in a mixture floats in a given medium and another sinks), and chromatography (differences in the size of molecules of different substances cause them to travel through a given medium at different rates). When the atoms of one or more substances rearrange to produce one or more different substances, this is called a chemical reaction. When two or more substances are combined, a chemical reaction may occur. When two or more substances are combined and *no* chemical reaction occurs, the substances form a mixture of those original substances.

Mixtures can be homogeneous or heterogeneous. Heterogeneous mixtures are mixtures with a nonuniform composition, such as a mixture of sand and iron filings. Since the sand and iron filings remain separate, the mixture is heterogeneous. Sugar dissolved in water is an example of a homogeneous mixture. The composition of the mixture is the same throughout. Some substances, such as milk, appear to be homogeneous to the naked eye, but they are actually heterogeneous mixtures. Looking at milk under a microscope reveals a nonuniform mixture of fat globules suspended in a liquid.

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Students consider the combination of 4-Methylcyclohexanemethanol (MCMH) and water—does the combination result in a mixture of the two substances or a chemical reaction? In 2014, a company called Freedom Industries accidentally spilled 7,500 gallons of MCMH into the Elk River in West Virginia. MCMH is an organic compound that the company used for cleaning coal. It does not react chemically with water, so it forms a mixture. From the Elk River, the MCMH made its way into local water supplies for 300,000 people since filtration systems used by water districts did not remove the chemical from the river water. Little is known about the health effects of MCMH, although residents reported headaches and burning eyes. There were no known ways to remove MCMH from the water, so residents were advised not to use the tap water until all the contaminated water could be flushed from the system, a process that took several days.

Instructional Guide

Explore and Activate Prior Knowledge

1. **Review substances, properties, and groups of repeating atoms.** Invite students to review what they have learned about what makes one substance different from another. Ensure that the class reviews both the idea that different substances have different properties and the idea that each substance is composed of a particular group of repeating atoms. Point out that students are considering substances at both a large scale (properties) and at the extremely small scale of atoms.
2. **Review chemical reactions.** Invite students to review what they have discovered about what happens during a chemical reaction. Ensure that the class reviews both the idea that in a chemical reaction the atoms of the reactants rearrange to form new substances (the products) and the idea that products have different properties than the reactants. Point out that once again, students are thinking at two different scales.
3. **Demonstrate combining four substances: iron, sugar, wax, and sand.** Explain that you will combine four different substances, and the class will look for evidence of whether or not a chemical reaction occurs. One by one, hold up each of the four bags with the individual substances in them and have volunteers point out several properties of each. Next, combine all four substances into one of the empty bags. Close the bag and mix thoroughly. Invite observations.
4. **Groups examine the combined substances.** For each group of four students, distribute one bag of the mixture and explain that these have the same combined substances as your demonstration. Have groups observe the combined substances, ask questions about what they observe, and look for evidence of whether or not a chemical reaction has occurred.
5. **Discuss whether a chemical reaction has likely occurred or not occurred.** Invite volunteers to share claims and evidence. [No, you can still see the original four substances, which appear to have their original properties.] It is okay if the class is not sure if a chemical reaction has occurred or not.

Construct New Ideas

6. **Introduce the challenge to separate the original substances from the mixture.** Explain that one way to be more sure that you still have the original four substances would be to see if you can separate them back into four individual substances again. Explain that this kind of challenge—separating substances—is one faced by certain engineers. Students will act as engineers, designing a method that can separate the four substances. These methods may involve several steps, and the designs should work, even for large amounts of the mixture. The solution to slowly pick apart the tiny pieces by hand is not acceptable.

7. **Introduce materials and guidelines.** Hold up a tray of materials. Explain that groups do not need to use all the materials, but all the materials should stay on the tray. Point out where students can get water for their cups, if they decide to use water.
8. **Groups explore ways of separating the mixture.** Have groups begin exploring ways to separate the substances in the mixture. Encourage them to try many ideas and to try to identify the causes and effects of the steps they find successful.
9. **Share ideas and successes.** After 10–20 minutes of exploration, have groups set all materials aside. On the board, write "sugar," "iron," "wax (paraffin)," "sand (silica)." Explain that these are the four substances in the mixture. Having the names will help different groups share ideas and understand one another. Call on groups to share what they have figured out and any successes they have encountered. Encourage groups to ask one another questions.
10. **Emphasize use of properties in separating mixtures.** As groups share successes, point out the way their separation techniques relate to a property of one of the materials. For example, say, "When you placed the magnet by the mixture, only iron stuck to the magnet. That is because being attracted to magnets is a property of iron but not of the other substances in the mixture." Or, "Paraffin floated in water because it is less dense than water." (You may want to remind students of the density investigation they conducted with different metals.)
11. **Groups continue testing, finalize their designs, and record their results.** Have students turn to the Part 1: Separating Substances Design student page. If no groups have tried putting the mixture into water, or if no groups have tried using the magnet, encourage students to try these methods. Distribute a second bag with the mixture to each group. Give groups another 10–15 minutes to test new ideas, determine the best plan for separating the mixture, and record their designs on the student page.
12. **Class shares.** Invite further sharing and discussion of designs. Once again, highlight ways that successful separation techniques relate to a property of any one substance.
13. **Introduce the word *mixture*.** Explain that when substances are mixed but are able to be separated again, this is strong evidence that a chemical reaction did NOT occur. Instead, these substances, when combined, formed a mixture. In a mixture, the combined substances still have their original properties, and the substances can be separated from one another (although it can be challenging). Write "mixture" on the board.

    In chemistry, a mixture is matter that is made of more than one substance.

    Students can also find the definition in the glossary at the back of their student booklets.
14. **Demonstrate combining sugar and water.** If at least one group dissolved sugar in water, highlight this for the class. If not, point out that this was a possibility. Hold up a cup of water, measure 1 tablespoon of sugar into the water, and stir. Describe that the sugar is no longer visible as a white solid.

15. **Discuss whether a chemical reaction occurred.**

    Do you think a chemical reaction occurs when sugar and water are mixed? What is your evidence?

    Call on volunteers to share claims and evidence, agree or disagree, or ask one another questions. [Agree: The property of sugar as a white solid changes. Disagree 1: Sugar's sweet property remains unchanged. Disagree 2: They have experience separating sugar from water.]

16. **Discuss and set up possible methods for separating sugar and water.** Invite student suggestions for how to separate sugar from water. If no one suggests evaporating the water, suggest it yourself.

17. **Distribute 1 dropper bottle, 1 plate, and 1 piece of tape to each group.** Explain that the bottles contain a combination of sugar and water. Have each student squeeze one drop of sugar water onto their group's plate, making the drops in separate locations. Have each group write their initials or a group number on the tape and affix it to the plate.

18. **Ask students to discuss what they think might happen.** Explain that students will let the plates sit undisturbed for 1–2 days.

19. **Prepare for second teaching day.** Be sure the water from the drops has evaporated before beginning. One or two days should be enough, depending on the temperature and humidity in the room. Note that the sugar crystals can be quite shiny and may appear, at first glance, to still be wet, even after the water has evaporated.

20. **Students read a short article about mixtures.** (Students can read this article at the end of the first day or at the beginning of the second day.) Explain that students will gather more evidence about the sugar water and other mixtures by reading an article. Have students turn to "This Is Not an Oxygen Tank" in the student booklet. Have pairs read the short article and annotate it with their ideas, questions, and connections. As pairs finish, they should share and discuss their annotations and the reflection questions in the Part 2: Reading "This Is Not an Oxygen Tank" student page.

21. **Return to the evaporated sugar water.** Have students make observations of the sugar-water droplets. Encourage students to touch the drops and discuss what they notice. Have students discuss what they think happened to the drops. [The water evaporated into the air, and the sugar stayed on the plate.] Also have students discuss whether the sugar and water made a mixture or changed in a chemical reaction. [It is probably a mixture since the sugar and water separated again.]

22. **Direct students to the atomic scale evidence of sugar and water.** Ask what other kinds of evidence could help determine whether there was a chemical reaction between the sugar and the water. If no one suggests atomic scale evidence, prompt students to consider scale when thinking about possible evidence. After some discussion, have

students turn to the Part 3: Sugar-Water Separation student page, and invite pairs to discuss what they think it shows. [There was no reaction; the sugar and water molecules are unchanged.] Call on a volunteer to share with the class.

23. **Students explain what happened when the water evaporated.** Point out the writing prompts at the bottom of the Part 3 student page and give students a few minutes to record their answers.
24. **Highlight the main idea of the lesson.** Emphasize that a mixture is a combination of different substances. However, for some mixtures, it is not easy to tell that there are multiple substances. A mixture can be separated by making use of the different properties of those substances.

Apply New Ideas

25. **Have students complete Part 4 student page.** Have students turn to the Part 4: Contaminated Water Separation student page. Read aloud the introduction and instructions. As needed, review the evidence (Properties table, Atomic Scale images) and the questions. Help students understand what is meant by temperature at which the substance boils and by density. Reassure students that there is not one right answer about how to separate MCMH from water.

Rubrics for Assessing Understanding of Mixtures

The rubrics below and on the next page may be used to review students' conclusions in order to formatively assess students' developing understanding of Crosscutting Concepts and Disciplinary Core Ideas.

Rubric 1: Assessing Students' Understanding of the Crosscutting Concept of Scale, Proportion, and Quantity

Note that this rubric applies to the Part 4: Contaminated Water Separation student page. Rubric 1 considers how well students are able to apply the crosscutting concept of Scale, Proportion, and Quantity to a specific phenomenon. This rubric may be used formatively to support students with the crosscutting concept of Scale, Proportion, and Quantity. Students will have more opportunities to apply this crosscutting concept throughout the rest of the *Chemical Reactions* unit.

Rubric 1: Assessing Students' Understanding of the Crosscutting Concept of Scale, Proportion, and Quantity		
Criteria	**Description and possible feedback**	**Level**
Consistent with accepted science ideas. Do students' responses show understanding that phenomena can be observed at various scales by using models to study systems that are too large or too small?	Students only use information about the observable-scale properties of the river in determining whether a mixture formed or if there was a chemical reaction. Possible feedback: *What happens to substances during a chemical reaction? How can you get evidence about that?*	0
	Students use information from the molecular models as evidence in determining whether a mixture formed or if there was a chemical reaction.	1

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to the Part 4: Contaminated Water Separation student page. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative, and space is provided to note if students are demonstrating understanding or are struggling with each idea. If students are having difficulty with a particular idea or with multiple ideas, you may consider returning to the sugar-water mixture investigation and leading a student discussion. Use Evidence: Atomic Scale and focus on how the evidence can be used to show that it is a mixture of sugar and water and on how the properties of the substances were used to separate the sugar and water when the water evaporated. (Water evaporates at a lower temperature than sugar.)

Rubric 2: Assessing Students' Understanding of the Science Ideas Encountered in the Unit		
Criteria	**Description**	**Is there evidence of student understanding?**
Consistent with accepted science ideas. Are students' conclusions consistent with accepted science ideas?	Students demonstrate understanding of the idea that substances are made of one type of atom or combinations of different types of atoms and that mixtures are physical combinations of one or more samples of matter. Example: The water and MCHM formed a mixture. When you look at the atomic scale evidence, the groups of atoms that make up water and the groups of atoms that make up MCHM are still there, so the substances are there.	
	Students demonstrate understanding of the idea that mixtures can be separated by physical means. Example: The water and the MCHM can be separated because they are a mixture. They could be separated by making the temperature between 100°C and 202°C so the water will boil off, but the MCHM will stay.	

Investigating Mixtures

Part 1: Separating Substances Design

With your group, design a method for separating the substances in the bag. The bag contains sugar, iron, wax, and sand. Describe each step of your method and list what substances are separated by each step.

Description of step	Substances separated by the step	Why did the substance(s) separate?
1. We moved the magnet through the mixture.	Iron	Because the iron was attracted by the magnet, and the other substances were not.
2. Once the iron was out, we put the mixture into water. The wax floated, and we scooped it out with the plastic spoon.	wax	Because the wax was less dense than the water and the sand.
3. We stirred the remaining mixture into the water until the sugar dissolved. We poured the liquid through the sieve into another cup. The sand got caught in the sieve.	sand	Because the sand pieces were bigger, they got caught in the sieve.
4.		
5.		

Investigating Mixtures (continued)

Part 2: Reading "This Is Not an Oxygen Tank"

1. Read and annotate the "This Is Not an Oxygen Tank" article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one that you would like to discuss with the class.
4. Discuss the reflection questions below.

Reflection Questions:

How is the diving tank similar to and different from the bag that was filled with four substances?

It's similar because both are a mix of different substances. It's different because the diving tank is all gases, and the bag contained all solids.

How is the diving tank similar to and different from the sugar water?

It's similar because in both the diving tank and the sugar water, you can't see the different substances. It's different because the diving tank has all gases, and the sugar water is a solid and a liquid.

Active Reading Guidelines

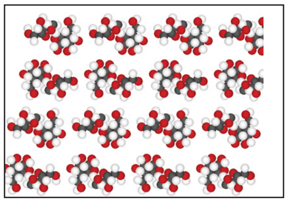
1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Investigating Mixtures (continued)

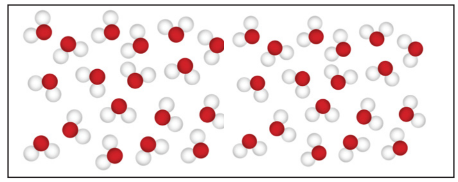
Part 3: Sugar-Water Separation

Make observations of the sugar-water drops on the plates and the atomic scale evidence below to answer the questions on this page and the next page.

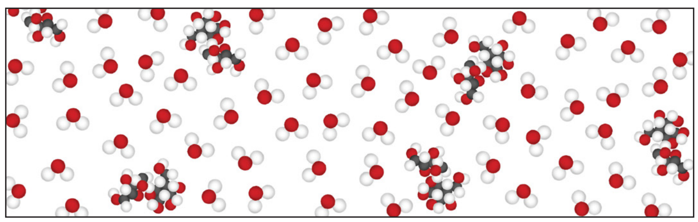
sugar



water



sugar mixed with water



When sugar and water are combined, does a chemical reaction occur or does it just form a mixture of sugar and water? Use evidence from the sugar-water drops and the atomic scale diagrams.

A chemical reaction does not occur when sugar and water are combined. They just form a mixture. When we left sugar-water drops on the plate, sugar was left behind. The atomic scale evidence shows that the molecules of sugar and water did not change when they were mixed.

Explain what you think happened to the drops of the sugar mixed with water that were left on the plates.

I think the water molecules evaporated and went into the air, which means only the sugar molecules were left on the plates.

Investigating Mixtures (continued)

Part 4: Contaminated Water Separation (continued)

Do you think a chemical reaction occurred when the MCMH mixed with the water? Why or why not?

No, I don't think a chemical reaction occurred. The diagrams show that the atoms that make up the molecules have not rearranged. They are still the same molecules. Also, the licorice smell of MCMH was still there. I think the MCMH and water made a mixture.

Someone who observed the river made the following comment: *I can't see the individual substances, so it must not be a mixture.* Do you agree or disagree with this? What is your evidence?

I disagree. Just because you can't see two different substances, doesn't mean there aren't two different substances. In the atomic scale evidence, the MCHM molecules and the water molecules are the same as they were before.

What is one idea you have about how MCHM could be separated from water? Why do you think that might work?

The MCMH molecules are bigger than the water molecules, so I think if you made a filter with holes just a little bigger than water molecules, you could separate the mixture.

OR

MCMH is less dense than water, so it should float on top of the water. I think you could suck up the top part of the mixture to remove the MCMH.