Session 4

Chemical Changes and Conservation of Matter

Where does the weight go when we "lose weight"? What happens when iron rusts? Why are exploding stars able to turn other elements into gold when the alchemists were not? In this session, we will extend and refine the particle model by taking a closer look at the particles—atoms and molecules—and will discover how the law of conservation of matter applies to chemical changes.

The Video

We begin our investigation into the nature of particles by observing that they have distinct sizes and shapes. Is this the explanation for the "missing volume" of the shaken mixture of water and alcohol in Session 3? Our hosts introduce the idea of chemical changes and show an example of one way that they are distinguished from physical changes.

Throughout this session, we visit Rebecca Cituk's classroom in Portsmouth, Rhode Island, where we listen as her sixth graders discuss the differences between chemical changes and physical changes and elements and compounds, and perform a classic experiment to see if matter is conserved in a chemical change. We return to the Science Studio where the interviewer uses a different approach—manipulatives—to help Cameron, a fifth grade student, explore a chemical change in which two clear liquids combine to form an opaque white solid. Both of these instances raise the following question: What happens on the particle level that makes chemical changes different from physical changes?

We then take a step back as science historian Mimi Kim takes us on a historical journey through the development of the modern science of chemistry, beginning with Étienne Geoffroy's "affinity table" in 1718. Along the way, we revisit some of the experiments of Lavoisier and Boyle that broke substances down to their simplest components—elements—and provided the first evidence for the law of conservation of matter.

Our hosts pick up the journey, noting the contributions of Proust, Dalton, Avogadro, and Sir William Robert Grove, whose electrolysis of water experiment they recreate as a real-world example of the law of fixed proportions. We conclude the journey with Mendeleev's organization of the elements into the periodic table and ask astrophysicist Dr. Robert Kirshner "Where did the elements come from?"

Learning Goals

During this session, you will have an opportunity to build understandings to help you:

- Refine and extend the particle model to develop an atomic model of matter, and become familiar with some of the history of the evolution of this model
- Recognize that chemical changes alter particles by rearranging their component atoms into different combinations
- Recognize that matter is not created or destroyed during chemical changes
- Recognize that the total number of atoms of each element is conserved during chemical changes

On-Site Activities

Getting Ready (60 minutes)

Activity One—Problem Set and Reading Discussion (20 minutes)

1. With a partner, review and discuss each other's conservation of matter and physical changes concept map. Were you able to connect this map with the particle model map from Session 2?
2. Discuss the Ruth Stavy article in a small group. What does her research tell us about the challenges that elementary students face in "acquiring" the concept of conservation of matter?
3. To prepare for this session, you were asked to think about examples of what might be classified as chemical changes. Share your examples with the whole group.

Activity Two—Chemical Changes (20 minutes)

1. With a partner, take one of the examples of chemical changes from Activity One and compare it to a physical change from the last session. Contrast the physical and chemical changes on both a macroscopic and microscopic level.
2. Draw a picture of what you think the surface of a nail looks like under a powerful microscope both before and after it has rusted. Do you think the nail would weigh more or less after it had rusted? Discuss your drawings and predictions in a small group.

Activity Three—Particles to Atoms (20 minutes)

Facilitators: Distribute the Session 4 materials.

1. With a partner, describe the smallest particle of each of the sample blocks or pieces that could still be considered that material (i.e., the metal is still the metal, the wood is still the wood, etc.). Is this "particle" an atom? If not, what is it?
2. As a whole group, build a working definition of the word "atom," and state which substances have atoms as their smallest particle that can still be considered to be made of that substance. Record the group's answers; you will revise these ideas later.

Watch the Video (60 minutes)

As you watch the video, think about the following focus questions:

1. What is the definition of a chemical change, and why does it seem to be irreversible?
2. As you watch the students in the Science Studio being interviewed, think about how you would refine the particle model to help them understand the chemical changes they are investigating.
3. When Rebecca Cituk's sixth graders first try their conservation of matter and chemical changes experiment, they get mixed results since their system was partially open. How might you use a similar challenge to teach your students about open and closed systems? About the scientific process?

On-Site Activities, cont'd.

Going Further (60 minutes)

1. How are your ideas about chemical and physical changes evolving? Answer these questions with a partner:
   a. What is the microscopic difference between chemical and physical changes?
   b. What is the best way to think about conservation of matter on a microscopic level? A macroscopic level? Which of these would be easier to present to your students?
2. Share your example of a chemical and physical change from Activity 2 in Getting Ready with the group. For each unique chemical change, describe the pieces of macroscopic evidence that support the idea that the changes are, in fact, chemical. How might you use the different colored blocks seen in the Science Studio to explain your chemical change on a microscopic level?
3. As a group, organize your materials from Activity 3 in Getting Ready into elements and compounds based upon the makeup of an individual "particle" of that substance.

Facilitators: Distribute the remaining Session 4 materials.

4. With your partner, try the following experiment:
   a. Pour a cup of vinegar into a soda bottle.
   b. Pour a tablespoon of baking soda into an un-inflated balloon.
   c. Gently take the balloon and seal the top of the bottle with it, being careful not to let any of the baking soda fall into the vinegar.
   d. Place the bottle on a gram scale and, record the weight.
   e. Take the bottle off the scale and without breaking the seal, hold the balloon upright, letting the baking soda fall into the vinegar.
   f. Share predictions with your partner about whether you think the bottle will now weigh less, more, or the same.
   g. Weigh the bottle again and record the weight. Discuss with your partner what you think is happening.

Between Sessions

Homework (* = required)

* Reading Assignment

Raghavan, Kalyani; Kesidou, Sofia; and Sartoris, Mary (1993). "A Model-Centered Curriculum for Model-Based Reasoning in Science." *Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*. J. Novak. Ithaca, New York, Cornell University.

As you read, think about how to expand children's prior ideas about pressure in liquids to include an understanding of the balance of forces. How does the MARS curriculum address this challenge?

* Physical Science Problem Set

(Suggested answers are listed in the Appendix.)

1. Explain the differences and relationships among these terms: element, molecule, atom, and compound.
2. In the video, the hosts mixed plaster of Paris with water, let it harden, and then tried to repeat the process with this hardened product and water. What was the macroscopic evidence that a chemical reaction had taken place? If we had a powerful microscope, would we see microscopic evidence that a chemical reaction had taken place? Answer the same questions for the "cheese candle" that the hosts burned at the end of the program.
3. How is Geoffroy's affinity table different from Mendeleev's periodic table? What is the usefulness of each?
4. Why is the example of electrolysis of water such a good demonstration of the law of fixed proportions? How can we be sure that this ratio of two hydrogen atoms to one oxygen atom holds true even down to the smallest particle?
5. Tony has a double pan balance. On one pan he puts an uncovered container of water and an Alka-Seltzer tablet. On the other pan he puts an uncovered container of water and places an Alka-Seltzer tablet in the water. As the Alka-Seltzer fizzes in the water, what do you think will happen to the pan holding the fizzing Alka-Seltzer?

* Ongoing Concept Mapping

Develop a concept map around the idea of the microscopic picture of chemical changes and how this relates to conservation of matter. Try to include the following concepts:

- Chemical change
- Conservation of matter
- Number of atoms
- Atomic model
- Periodic table
- Atom
- Compound
- Physical change
- Number of particles
- Particle model
- Law of fixed proportions
- Essential properties
- Element
- Molecule

Between Session, cont'd.

Guided Journal Entry

At this point in the course you've reached a basic understanding of how substances undergo chemical changes. Think about the refinements we made to our model in Session 4. What macroscopic behaviors of matter are still not explained sufficiently with our newly expanded model (e.g., what makes a piece of styrofoam float or a rubber ball bounce)?

Textbook Reading Suggestions

The following are suggestions for several reading topics that may provide additional background and enrichment information. These topics are likely to be addressed in any college-level physics or chemistry textbook.

- Chemical change
- Precipitation
- Dalton
- Boyle
- Proust
- Law of definite proportions
- Molecule
- Element
- Periodic table
- Electrolysis
- Conservation of matter
- Solubility
- Lavoisier
- Avogadro
- Affinity table
- Compound
- Atom
- Ionic solid
- Mendeleev

* Preparing for the Next Session

For "Getting Ready"

Before the next session, try to estimate the volume in cubic centimeters of a few objects that you encounter every day. Use the following for reference:

1 cm^3 = The size of a single six-sided die

100 cm^3 = About the size of an apple

1000 cm^3=1 liter, half the volume of a 2-liter soda bottle

How could you accurately measure the volume of these objects? Write down your observations and bring them to the next session.

Materials Needed for Next Time

- Aquarium or similar-sized tank filled with water
- Balloons
- 250 ml beakers, or same-sized glass/clear plastic cups
- Long wax dinner candles that can be cut into pieces
- Rubbing alcohol (Isopropyl)
- Drinking glasses
- Rubber bands
- Gram scales

Graduate Credit Activities

Continue your work on the annotated bibliography and action research project.

Notes