

## Enhancing student understanding of physical and chemical changes

by Julie McIntosh, Sandra White, and Robert Suter

Students within the Findlay, Ohio, City School District, as well as students across the country, struggle with understanding physical and chemical changes. This article explores the assessment of the National Science Education Content Standard B for grades 5–8: “All students should develop an understanding of properties and changes of properties in matter...Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions the total mass is conserved. Substances are often placed in categories of groups if they react in similar ways, for example, metals” (NRC 1996).

We suggest activities to clarify misconceptions and provide formative assessments to measure your students’ progress as they determine the differences between chemical and physical changes.

Using the Ohio Department of Education (ODE) website, which allows school districts to search released questions and determine which standards and concepts students are experiencing difficulty in answering, we conducted an item analysis to determine which concepts students were struggling with across the district. Curriculum directors and principals have access to these data from the Ohio Department of Education website. Other states have similar systems with administrative access (ODE 2004). From our analysis, (using the ODE item analysis that shows overall percentages of students who chose the wrong answers, and how this compared with the rest of the state), we found that students struggled with the following questions:

1. Popcorn kernels contain a solid material called starch and a small amount of water at room temperature. When the temperature of the kernels of popcorn increases, they explode or pop. Which change in the state of the water takes place inside the kernel, causing volume to increase?

- A. solid to gas
- B. liquid to gas [correct answer]
- C. solid to liquid
- D. liquid to solid



This question measures students’ ability to identify and describe physical properties of matter in various states. In our district, 27% of students answered this question correctly; the percentage was even lower (24%) across the state.

In order to compare the characteristics of simple physical and chemical changes, the following question was analyzed:

2. Students conduct investigations with solids and liquids over several days. Students pour vinegar into a beaker. They add a spoonful of baking soda to vinegar. They observe bubbles. The bubbles stop when the baking soda is no longer visible. What observation suggests that a gas is formed?

- A. The baking soda disappears.
- B. Bubbles are formed in the vinegar. [correct answer]
- C. All chemical reactions produce gas.
- D. The vinegar begins to give off a smell.

Forty-six percent of students in our district answered this question correctly, 52% across the state. This question shows a lack of student understanding on chemical changes.

Our analysis revealed that both state and district students had not mastered an understanding of physical and chemical changes.

### Preassessment

In the following pages, we suggest activities that will strengthen student understanding of physical and chemical changes. It is always good to preassess your students’ understanding before beginning a lesson. One simple approach to preassessment would be a KWL chart about chemical and physical changes (what they *know*, what they *want* to learn, and what they have *learned*), filling out the Know and Want to Learn columns. The Know

**FIGURE 1** Demonstrations

Demonstration	Questions	Safety
<b>Physical changes</b>		
Tearing paper	Is the change to the paper physical or chemical? Ask students to support their answer that the chemical composition has not changed, just the shape and size. If students still don't understand the change in size and shape, they can fit the pieces back together and determine if it is still a piece of paper.	General classroom safety
Mixing salt and water and then boiling	What are the parts of this mixture? What happened to the salt? What happened to the water? What inference can you make?	General classroom safety and heat caution
Popping popcorn	Have students research and diagram a cross section of a popcorn kernel to reveal the water trapped inside. Can you elaborate on the reason that popcorn pops? What happens to the starch in the popcorn kernel? This is something that students will probably ask about, too. What kind of change is it and why? What about the kernels that do not pop—ask students to think of the causes for this. What about the kernels that burnt or get scorched?	General classroom safety and heat caution
<b>Chemical changes</b>		
Burning wood can be done outdoors with proper safety or you can find a video.	What elements are found in wood? How did these elements get there? What combinations of compounds could be created from these elements? This would be a good time to introduce reactants and products as well as conservation of mass. What change is taking place and what evidence do students observe that a chemical change is taking place (e.g., thermal energy, light, smoke). The carbon, hydrogen, and oxygen inside the wood have combined with oxygen in the air to form new substances. If you don't have oxygen present (such as the flue of a chimney not being open), carbon monoxide is formed. Students could then draw an illustration of what took place or a concept map showing the reactants and products in this chemical reaction.	Proper ventilation is needed if done indoors, general safety and heat concerns
Electrolysis of water can be done using a nine-volt battery to decompose water into two parts hydrogen and one part oxygen. Two J hooks are positioned in a bath of water so that the curved ends are inserted into inverted test tubes. The other ends stick out of the water and are connected to a battery. The gas that is collected can be flame tested.	What elements make up water? In a decomposition reaction, what would be produced from the breakdown of water? Have students write a chemical equation for what is taking place with reactants and products. What could be done to increase the amount of oxygen and hydrogen being produced? Have students draw what is taking place inside the beaker as water is being broken down. You could also have students do their own research to determine what gases were produced rather than setting it up as a demonstration.	The flame test can be a demonstration or media can be found to show a great reaction to gas being collected, general classroom safety.

**FIGURE 1**

**Demonstrations**

<p>Passing a heavy, clear glass held sideways through the flame of a candle.</p>	<p>Have students observe what happens when you do this. You should see a brief “fogging” of the glass in the area around where the flame passed. You can also take the glass and exhale through your mouth onto the surface of the glass. This will produce the same kind of “fog” on the glass, even though it might be a lot more than what you see from the candle flame. This fog will evaporate very quickly. Where did the fog come from when you breathed on the glass? What about when you put it through the flame of the candle? It had to have come from the burning candle, but do candles have water in them? Candles are made from paraffin, which is a “hydrocarbon”; it is made from carbon and hydrogen. When a hydrocarbon burns, what happens to the carbon and the hydrogen? One possibility is that the hydrogen combines with oxygen from the air to make water. What happens to the carbon then? One possibility is that the carbon would combine with oxygen from the air to make carbon dioxide or carbon monoxide. Run the candle flame under the glass again. This time, hold it a little longer. You will see black soot collect on the glass. The soot is carbon. Is the candle flame a place where a chemical change is happening or is this just “physical” change? While the candle was burning, wax was running down its side. The melted wax that runs very quickly turned back into a solid. Is the melting of the wax a chemical change or a physical change? Students could write an explanation of what took place or complete the “Noting What I Learned” assessment.</p>	<p>General classroom safety, open flame</p>
<p>Have students place an Alka-Seltzer tablet in water. Alka-Seltzer is aspirin, citric acid, and baking soda, or sodium bicarbonate, and when added to water it forms carbon dioxide. Students can observe the bubbles, indicating a chemical change.</p>	<p>What is in an Alka-Seltzer tablet? Students could conduct research to determine what it is made of or you could share. Have students provide a chemical equation for what is taking place when you add Alka-Seltzer to water. They could also extend this activity to pH and buffer solutions. Place a flaming splint above the bubbles to identify the gas being formed. In this case, the carbon dioxide formed will extinguish the flame.</p>	<p>General classroom safety</p>
<p>Have students pour some vinegar into a little bit of milk in a glass. Students swirl the milk/vinegar mix around; soon they will see “curds” form and stick to the side of the glass.</p>	<p>Students can research the chemical makeup of vinegar and milk. What are the possible products that could be created? Using all of your senses, what observations have you made to determine that a chemical reaction has occurred?</p>	<p>General classroom safety</p>

<p>Mixing vinegar and baking soda</p>	<p>What observation can you make that a chemical reaction has occurred? The fizz of making a new gas is obvious. No amount of heating or cooling or squeezing is going to make the gas go away and return the vinegar and soda to us. This is another obvious change that is a strong clue that a chemical change has happened. What could be done to maximize the reaction?</p>	<p>General class-room safety, safety goggles</p>
<p>Clean the oil off some fine steel wool (steel wool is coated with a light oil to prevent it from rusting in the air; a good way to clean it is to rinse it in a little paint thinner). This should be done by the teacher. The steel wool will then need to dry overnight. Have students place the steel wool into some water in a clear glass and let it sit for a couple of hours. Students will see some rusty color develop in the water that gets worse the longer it sits.</p>	<p>What observations can you make in regard to the steel wool and the water? What reactants and products are we working with? What would happen if we left the steel wool in the water overnight? Why would it be important to protect steel wool from rusting?</p>	<p>General class-room safety, hand washing</p>

column will give you the prior knowledge that students bring with them to class as well as any misconceptions they may have. The Want to Learn column will help guide your lesson. The Have Learned column will be completed as part of the final assessment activities.

## Safety

For any of the activities in Figure 1, safety procedures need to be followed. Your classroom should be equipped with fire extinguishers and fire blankets. Extreme caution should be used with an open flame; all students and demonstrators must wear goggles and tie back hair. Proper ventilation must be in use. For more information, see Scope on Safety columns ([www.nsta.org/middle-school](http://www.nsta.org/middle-school)) and *Inquiring Safely: A Guide for Middle School Teachers* by Terry Kwan and Juliana Texley.

## Demonstrations

For most students, identifying whether a chemical or physical change has taken place when answering a test question is not easy at all. They have to look at all of the clues and then make the best judgment that they can. The ideas in Figure 1 may help you encourage students

to look for clues as to whether an item has undergone a physical or chemical change.

## Assessment

For any of the activities mentioned, you may want to have students complete a Noting What I Learned form to evaluate their thinking (Struble 2007). Students should write their thoughts about the activity or demonstration on the right side of the page, and make an illustration or graphic organizer of what occurred on the left side of the page. The sides of the columns have been aligned to go with the right- and left-brain hemispheres. What goes on the left are output items such as diagrams, graphs, drawings, concept maps, and reflections. The right side should contain the factual information related to what the student learned and the observations made during the demonstration or experiment to determine if a physical or chemical change occurred (Young 2003). As students begin to feel more comfortable with identifying chemical changes, you can begin to discuss that their observations indicate that a change has taken place and that the change cannot be “undone.” When you fry an egg,

you know it is done when the clear, colorless part called the “white” really does become white and solid, and the yellow part changes from a runny liquid to a solid. If you tried to reverse these changes by cooling the egg, you would fail. This is pretty strong evidence that a chemical reaction has happened. Students complete the What I Have Learned column of the KWL charts they created as a preassessment.

## Conclusion

By watching teacher demonstrations and conducting some of these hands-on activities, students can begin to see for themselves the differences between physical and chemical changes. Sample assessment questions from your state’s assessment system could be used as a pre- and posttest assessment for physical and chemical changes. The KWL chart and Noting What I Have Learned will help you assess what your students have learned regarding physical and chemical changes.

## References

- National Resource Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.
- Ohio Department of Education (ODE). 2004. *Academic content standards K–12 science*. Columbus, OH: Ohio Department of Education.
- Struble, J. 2007. Using graphic organizers as formative assessment. *Science Scope* 30 (5): 69–71.
- Young, J. 2003. Science interactive notebooks in the classroom. *Science Scope* 26 (4): 44–47.

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