Chemical Change

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Over the course of two 50-minute class periods, students will combine unknown reactants (two white solids, a clear liquid, and a bright red liquid) and experience them reacting in a closed plastic bag. Several different changes will take place. Students are challenged to write a description of the reaction and its products, then try to determine what reactants are responsible for the products and changes observed.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Chemical reactions produce observable changes in matter.

Students demonstrate this knowledge and understanding by recording observations during a chemical reaction and adjusting proportions of reactants to determine which combinations produce the different reactions and products.

Correlations to North Carolina Science Standards

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

Brief Science Background

In a chemical reaction, ingredients (reactants) both break *and* form chemical bonds. Changes in chemical bonds often cause the result (product) to have characteristics that are different from the reactants. Some reactions occur spontaneously, others require some input of energy to begin. When reactants produce a chemical reaction, the reaction often causes observable changes such as color change, a temperature change, production of gas, an odor, light, or a precipitate.

In the chemical change demonstrated in this investigation, a careful observer may see many of the changes listed above.

Details of the reaction are complicated, *not important* at this time, and should not be discussed with the students. However, for reference, the reaction is:

$$CaCl_2 + 2NaHCO_3 \rightarrow 2NaCl + CaCO_3 + H_2CO_3$$

$$H_2CO_3 \rightarrow CO_2 + H_2O$$

Calcium chloride (*Powder A*, $CaCl_2$, a salt) and sodium bicarbonate (*Powder B*, $NaHCO_3$, baking soda, a salt) combine, in the presence of water (*Liquid C*), to produce sodium chloride (NaCl, table salt), calcium carbonate ($CaCO_3$, lime, a salt), and carbonic acid (H_2CO_3). Carbonic acid is unstable and breaks down to carbon dioxide (CO_2) and water (H_2O). Phenol red (*Liquid D*) is a pH indicator and does not take part in the reaction.

Part 1 — Chemical Change (30-minutes)

Materials

Materials for the whole class

- Powder A, calcium chloride, $CaCl_2$
- Powder B, sodium bicarbonate, $NaHCO_3$
- Liquid C, water
- Liquid D, phenol red (500 ml)
- pre-printed labels for A, B, C, and D
- large zip lock bags for storing powders
- candle in a 3.5 oz plastic cup
- long match
- pint Mason jar with a new lid
- electronic balance
- copies of student instruction sheets (2 per team)

Materials for groups of 4 students

- 1 Powder A in a labeled and capped 3.5 oz cup
- 1 Powder B in a labeled and capped 3.5 oz cup
- 1 Liquid C (water) in a labeled 125ml dropper bottle
- 1 Liquid D (phenol red) in a 125 ml dropper bottle
- 2 medicine cups
- 2 zip lock sandwich bags
- 2 sets of measuring spoons
- 2 student instruction sheets (BLM 1)
- safety glasses (supplied by teacher)
- science notebook (supplied by teacher)

Preparation

1. Prepare the phenol red solution by filling the 500 ml bottle, which already contains the phenol red powder, with water. Use this stock solution to fill the dropper bottles labeled Solution D.
2. Fill the Liquid C bottles with water.

Procedure

1. Demonstrate the setup for the students:
2. Put 5 ml (1 teaspoon) of Powder A and 2.5 ml (1/2 teaspoon) of Powder B in the sandwich bag.
3. Put 5 ml of Liquid C and 10 drops of Liquid D together in a medicine cup.
4. Set the medicine cup containing the liquid in the bag, but DO NOT turn it over.

Procedure Cont.

5. Flatten out the bag between your hands and seal the bag.
6. Tell students that when they get this far they will turn over the cup of liquid so it pours onto the dry ingredients and observe what happens.
7. Before handing out the materials, tell students to put on eye protection and that they should avoid either ingesting or inhaling any of the "ingredients" for the experiment. Hand out the materials and the student directions and let the students go to work.
8. As students finish watching the reactions ask them to write a list of the changes they observed. Discuss the students' lists of observed changes. Here are changes that students might notice:
    - The reaction fizzes, producing bubbles of gas that partially inflate the bag if it was well zipped.
    - When one of the white powders dissolves in the liquid and gas is released, the chemicals cool a little and part of the bag feels cool. When the other white powder dissolves in the liquid, the bag gets warm. Depending on how reactants mix in the bag, students may feel both hot and cool at different places in the same bag at the same time.
    - The liquid changes from bright red to orange or yellow.
    - A white substance forms and makes the liquid cloudy. This might be hard to see because some of the reactants may still be undissolved.
9. If some students disagree on what they observed, ask the whole class to run the procedure again to see if everyone can observe the same changes. If there are no disagreements about observations, there is no need to run the standard bag setup a second time. If the class does a second run of the procedure, discuss any new observations.

There is no need at this time to discuss why students observed what they did. For the teacher's information only, the following points explain some of the students' observations:

- The reaction produces enough bubbles of carbon dioxide (CO_2) to partially inflate the bag.
- The act of dissolving the baking soda in water causes cooling. The reaction between calcium chloride and water produces heat.
- The product of the reaction between calcium chloride and sodium bicarbonate in water is carbonic acid, which changes the pH from basic to acidic and causes the phenol red to change from bright red to orange or yellow.
- The carbonic acid in solution rapidly breaks down to produce carbon dioxide gas which bubbles and fills the bag.
- One reaction product is calcium carbonate, a white precipitate that clouds the water. Leftover calcium chloride and sodium bicarbonate make this hard to see. Sodium chloride is also a product, but it tends to remain dissolved and does not cloud the water.

Wrap-Up

1. Say that early chemists first observed reactions, and then tried to figure out what caused each part of them. They investigated the reactants in one way, the reaction another way, and analyzed the products in another way. This approach led them to understand what different substances were made of. For

example, an early chemist produced an unknown gas in a chemical reaction. To find out what the gas might be, he placed a candle in a jar of the gas. He saw that the candle burned more brightly than usual. From this, he thought that the gas might be something in air that allows things to burn. Eventually, this led to the discovery of oxygen.

2. Ask students to write some procedures that they might use to investigate the reaction they have observed.

Part 2 — Chemical Change 2 (30-minutes)

Materials

Materials for groups of 4 students

- 1 Powder A in a labeled and capped 3.5 oz cup
- 1 Powder B in a labeled and capped 3.5 oz cup
- 1 Liquid C (water) in a labeled 125 ml dropper bottle
- 1 Liquid D (phenol red) in a 125 ml dropper bottle
- 6 medicine cups
- 6 zip lock sandwich bags
- 2 sets of measuring spoons
- 2 student instruction sheets (BLM 1 from previous lesson)
- safety glasses (supplied by teacher)
- science notebook (supplied by teacher)

Preparation

1. Prepare the phenol red solution by filling the 1 liter bottle with water. Use this stock solution to fill the dropper bottles labeled with Solution D.
2. Fill the Liquid C bottles with water.
3. Fill 3.5 oz labeled cups with Powder A and Powder B.

Procedure

1. Ask students to share their ideas of what they might do to investigate the reaction in the bag to try and figure out what reactants caused the changes they observed. Hopefully, students will come up with the idea of changing the recipe to observe what happens differently. For example, they might leave out a reactant. If they do not come up with recipe changes on their own, explain that early chemists tried simplifying reactions by using fewer reactants and observing the reaction and products.
2. Challenge pairs of students to work together to develop three new recipes that might help them study the reaction. Tell them that they can leave out whatever they want but that they are not allowed to more than double any reactant. The limit on amount of reactants helps to avoid exploding bags due to gas buildup caused by large amounts of reactants.
3. Ask the students to record their recipes in their notebooks with detailed entries of their observations.

Wrap-Up

1. Ask students to write their conclusions in the form of, "Reactant X + Reactant Y results in _____" on strips of paper and have them post the strips where students can see them all together and compare them. Discuss what students observe. In the discussion try to bring out two things:

   a. a class consensus about what each reactant brings to the reaction and its products

   b. ideas about what to do when results using the same reactants differ.

2. Explain that chemists often use different types of equipment to study a reaction. Inside the mason jar, carefully place the same reactants in the same containers that were used in the bag. <u>Tighten the lid down very hard</u>. Take care when tightening the lid not to tip over any ingredients in the bottle. You do not want a reaction yet.

3. Display the mason jar with lid on and explain that, in a few minutes, you will tip the jar to start the reaction. Ask the class for possibilities of what might happen when the reactants combine. Students might say:

   - The reaction will be as usual.
   - There will be no reaction because there is no room for the gas.
   - The reaction will be as usual and jar will explode because it can't expand like the bag.

4. After this discussion and before starting the reaction say, "Early chemists were interested in the amounts of reactants and products in reactions. If I weigh the jar before and after the reaction what might the results be?" Ask for student answers and their reasoning. Keep pushing to get all three possibilities: same weight, more weight, or less weight. Weigh the jar and record the weight before the reaction. Inform students that the scale is accurate within 0.1 g.

5. Tip the jar and shake the reactants to start the reaction. Ask students to point out what is happening in the jar. Weigh the jar again. The weight should be unchanged. Say that other early chemists also observed this. If they caught all of the reaction products of any chemical reaction, the starting and ending weights were the same. Whenever all reactants and products are weighed and not allowed to escape, the setup always weighs the same before and after. This is called conservation of matter. In a chemical reaction, matter changes but is never lost. It is always "conserved." This was a strong clue that matter is made up of parts that can rearrange.

6. Finish discussing all questions about conservation of matter and inform the class that we can still investigate the gas that was produced.

7. Say, "We know some gas was produced because we saw bubbles. Early chemists often used a candle to test an unknown gas. Light a candle and place it in a 3.5 oz plastic cup. Ask the class what could happen when you open the lid and pour the gas out of the jar and what each of the possibilities mentioned could indicate. Possibilities include:

   a. Nothing happens so the gas must be just like the air around us.

b. The candle burns brighter so the gas contains more of what a candle needs to burn.

c. The flame explodes, so the gas must contain some fuel.

d. The candle burns dimmer, so it must not be like the air around us.

e The candle goes out so the gas must be something that inhibits burning.

8. Open the lid slowly to release some pressure. Ask the class what the sound indicates. After the pressure is released, slowly tip the jar over the edge of the cup. You are pouring carbon dioxide, which is heavier than air. As the carbon dioxide fills the cup, the candle will go out. Be careful to not pour the liquid out of the jar. After the candle is extinguished light a long match and place it in the jar and watch it extinguish.
9. Ask the class for detailed descriptions of what they have just observed. They should see that an invisible gas was poured out of the jar and it extinguished the candle and then it extinguished a burning match.
10. Ask for predictions on what the weight of the jar is now. The weight will be between several tenths of a gram and nearly a gram less.
11. Ask what this tells us about the gas produced in the reaction. Students should notice that it has weight, it is invisible, it seems to be heavier than air (it pours down through the air) and it can extinguish a flame.
12. Say, "When early chemists discovered this kind of information, they started to wonder things such as:

a. What makes gases different from each other?

b. How are gases different from solids?

c. What makes substances different from each other?

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. Early alchemists and chemists often observed reactions and then worked backwards to figure out what was happening. They did this especially where many reactants were involved, as in our bag reaction. Comment on how each procedure might give insights into what reactions are happening in our bag:

a. Double the dry ingredients. Mix them together in the bag and let them sit for a week.

b. Double the amount of one reactant and see what happens.

c. Open the bag when you turn over the liquids.

d. Double one reagent and see if the bag inflates more.

2) A teacher was trying to convince students that conservation of matter always occurs in a chemical reaction. To do this, the teacher mixed vinegar and baking soda in a cup. Students had carefully weighed the ingredients and cup, and recorded the weight before the reaction. They combined the reactants in the cup and got a fizzing reaction. When the reaction was over, the class couldn't see any baking soda. However, the cup of mixed compounds weighed less than it weighed before the reaction. The teacher still says that whenever a chemical reaction occurs, what you start with (reactants) and what you end with (products) have the same weight. Which explanation below would be best for students to use to help their teacher understand why the law of conservation of mass appeared not to work?

a. Part of the cup dissolved into the vinegar so it all weighed less.

b. The fizzing is a gas produced during the reaction, so she needs to catch the gas to weigh it.

c. The baking soda disappeared so it all weighed less.

3) Students started proposing new experiments that would allow this reaction to prove the law of conservation of matter in a chemical equation. Which experiment or combination of experiments might supply evidence supporting the law, and why?

a. Do the reaction in a container made of glass.

b. Do the reaction with more reactants so they are easier to weigh.

c. Do the reaction in a container with a tightly closed lid.

d. Weigh all reactants and products before and after the reaction.

BLM 1

Student Instructions for Chemical Change

1. Put on your safety glasses.
2. Place 5 ml (1 teaspoon) of Powder A in the sandwich bag.
3. Place 2.5 ml (1/2 teaspoon) of Powder B in the same sandwich bag.
4. Put 5 ml of Liquid C and 10 drops of Liquid D together in a medicine cup. Place the cup in the same bag, but **keep it upright**!
5. Press the air out of the bag and zip the bag closed.
6. Tip the cup over and mix all the chemicals.
7. In your science notebook, write detailed descriptions of *everything you observed*.

Appendix

Common Student Preconceptions About This Topic

Children have difficulty distinguishing between elements, compounds, atoms, and molecules for reasons having to do with basic language. For example, elements are described as "pure" substances, meaning "made of only one thing." For many children, the term "pure" means "without harmful contents," or "clean, bright, and as-it-should-be." In addition, children have difficulty with the idea of "substance." For example, some middle school children see ice and water as different substances. In general, most children understand matter in a macroscopic way, not at a microscopic level. As a result, they tend to view chemical combination as a kind of mixing, with only a hazy idea of microscopic internal chemical bonds. For example, many think that burning is like evaporation, only faster because of the heat. Although they know that oxygen is necessary for combustion, they have little or no sense that it is interacting with the material that is burning.