VANDERBILT SCIENTIST IN THE CLASSROOM PARTNERSHIP

Chemistry in a Ziploc Bag (8th Grade)

Fall 2022

GOAL: To use the scientific method to explain observations made when calcium chloride, sodium bicarbonate, water, and phenol red are mixed.

Fits TN State standards:

5.PS1.4 Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties

7.PS1.2 Compare and contrast elemental molecules and compound molecules.

7.PS1.3 Classify matter as pure substances or mixtures based on composition

7.PS1.4 Analyze and interpret chemical reactions to determine if the total number of atoms in the reactants and products support the Law of Conservation of Mass

7.PS1.5 Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter.

LESSON OUTLINE

I. Introduction

Explanation of the scientific method and the importance of observations.

II. Experiments

A. "Inquiry-based" activity. Students work in pairs to observe the changes that occur when four different substances are mixed.

B. Using the Scientific Method. Students brainstorm how to determine which reagents caused which specific change observed.

C. Applying the Scientific Method. Students are assigned two reagents to react together.

III. Observations and Explanation

IV. Instructor Background Information on Chemical Equations

1. In the car ride before the lesson, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

Lesson Quiz

1. Why are scientific observations important? Why do they need to be recorded?
2. How was the phenol red indicator made and what is its purpose in the experiment?
3. What happens when calcium chloride is added to the baking soda/phenol red solution?
4. How many control experiments should each pair do?
5. What are some observations that would indicate a reaction took place?
6. What are some of the possible student observations? How can they be explained?

2. Use these fun facts during the lesson:

- **Phenol red**
  - It is used to test the pH of swimming pools. It is sometimes called "guardex solution #2"
  - It is used to monitor the pH of cells in cell culture. An excess of waste or bacterial contamination will cause the media to become acidic and the phenol red will turn yellow.
- **Calcium chloride**
  - It is put on roads in winter because it lowers the freezing point of water, preventing ice from forming.

- It is commonly used as an electrolyte in sports drinks and other beverages, including bottled water.
- The extremely salty taste of calcium chloride is used to flavor pickles.

- **Baking soda**, or sodium bicarbonate
  - Why is baking soda used in baking? Baking soda reacts with acids in bread to created carbon dioxide (similar to this experiment!) which creates bubbles that form the holes in bread.
  - It can neutralize acids and is used to treat indigestion, heartburn, and burns.
  - It is an ingredient in some toothpastes, mouthwashes, deodorants and shampoos. Ancient Egyptians used deposits of baking soda as soap.
  - Some types of fire extinguishers use baking soda to put out fires

MATERIALS

Note: Be sure you have all of the materials before you leave the lab.

15 plates
15 1 oz cups marked at the 15 mL level
15 Ziploc sandwich bags containing one spoonful of baking soda
1 250 mL container of phenol red solution
20 Ziploc sandwich bags
4 $CaCl_2$ stock containers
32 spoons
25 paper towels
Ziploc bags containing materials for each control experiment
2 bags of Control 1 - $NaHCO_3$ plus H_2O
2 bags of Control 2 - $NaHCO_3$ plus phenol red solution
2 bags of control 3 - $NaHCO_3$ plus $CaCl_2$
2 bags of control 4 - $CaCl_2$ plus H_2O
2 bags of control 5 - $CaCl_2$ plus phenol red solution
2 bags of control 6- H_2O plus phenol red
2 bags of control 7- $CaCl_2$ plus $NaHCO_3$ plus H_2O
1 trash bag
30 pencils (students use their own and need to have them ready to record observations)
1 PowerPoint/binder containing ppt, 32 Observation Sheets

1. In the car ride before the lesson, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

7. Why are scientific observations important?
8. What happens when calcium chloride is added to the baking soda/phenol red solution?
9. What must scientists do when changing variables in an experiment?
10. How many control experiments should each pair do?
11. What evidence of chemical reactions was observed?

2. Here are some Fun Facts for during the lesson:

Phenol red is also used to test the pH of swimming pools. It is sometimes called "guardex solution #2"

Your Notes:

_____

_____

_____

_____

Calcium chloride is used as "salt" to melt ice on roads.

Baking soda is sodium bicarbonate, and is used in fire extinguishers, baking, neutralizing acids and bases. It is also used to treat indigestion, heartburn, and burns. It is an ingredient in some toothpastes, mouthwashes, deodorants and shampoos.

I. Introduction

Organize students in pairs.
Give each student an Observation Sheet.
While one instructor gives the following explanation, the other instructor should pour phenol red solution in the 15 1 oz cups marked at the 15 mL level.

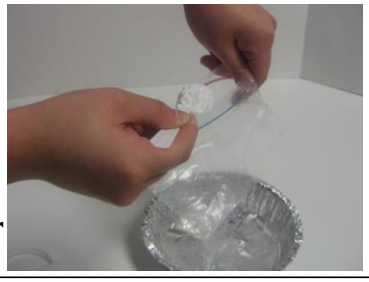
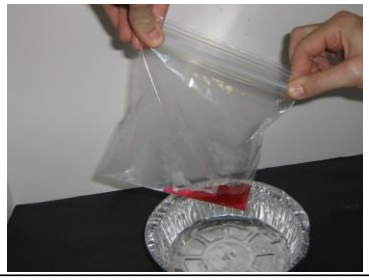
Explain to the students that all scientific knowledge is a result of careful investigation and observations. New discoveries and advances in science depend on having a careful and accurate record of observations made while investigating a question. That is why it is important to make accurate and detailed observations. At the end, scientists make a hypothesis, or try to explain their observations. They then design an experiment that tests their hypothesis.
NOTE: Phenol red solution was made by dissolving a small amount of phenol red powder in water, so when you add the phenol red solution, you also have to consider the effect of water on the reactions.

II. Experiment A – Making Observations When Calcium Chloride is Added to Baking Soda/Phenol Red Solution.

Give each pair one ziploc bag containing baking soda, one 1 oz cup containing 15 mL of phenol red solution, and one plate.

Tell students to:

1. Hold the bag upright over the plate.
2. Open the bag while an instructor goes around and adds a teaspoon of calcium chloride.
3. Add the phenol red solution (including water) to the bag and seal the bag.
4. **Gently** shake the contents of the bag while holding the bag over the plate.
5. Feel the bag (while keeping it upright) and record observations about color changes, temperature changes (is the bag cold or warm or both since there can be localized heating), changes in bag size, and gas given off or foaming.
6. The reaction takes about three to five minutes. During this time the student not holding the bag should write down any observations that the pair has made. Then, the students should switch. One should feel the bag, and the other should write observations.


Your

NOTE: There is no danger of the bag exploding if the correct amounts of chemicals are used. Since everything is pre-measured, you should have no problems. In the event one does explode or leak, use paper towels to clean up any mess. If the students have followed your directions, any spilled liquid will be on the plate, which can be easily wiped up with paper towels. Assure the students that the chemicals are safe.

Write student observations on the board.
Possible Student Observations:

(1) When calcium chloride was added to the baking soda, nothing happened.
(2) When the phenol red solution was added to the baking soda/calcium chloride bag, the color started changing from red to yellow (some students may say they saw some pink color – accept this as well.)
(3) The bag became cold (for a short time).
(4) The bag may be warm in some spots.
(5) The bag fills up with gas. There are bubbles.
(6) The bag may become cold again after a while.

Ask students which observations are indicators of chemical changes?
A color change, **a gas given off**, **temperature change,** or **the formation of a precipitate.**

II. Experiment B – Brainstorming To Determine Which Reagents Caused a Which Observation.

For this section, students will brainstorm how to determine which reagents caused a certain observation.

Write the following chemicals on the board:
sodium bicarbonate $NaHCO_3$, calcium chloride $CaCl_2$, water H_2O, phenol red
Ask students: *Which reagents are causing the specific changes that have been observed?*

Tell students that this cannot be easily determined by observing the reaction with all 4 chemicals, but it can be determined by systematically testing different combinations of reagents.
Tell students that they will determine which combination of chemicals produced the following observations:

1. The bag initially feels cold(er).
2. The bag feels warm(er).
3. The mixture turns from red to yellow.
4. The mixture fizzes, and the bag fills up with gas.

Take the students through the steps of a systematically designed procedure to test each observation by

Your Notes:

_____

_____

_____

_____

taking one variable (reagent) and combining it with one other reagent. Once they are done with that variable, they will go on to the next one until all possible combinations are tested. Tell students that scientists design experiments that keep only 1 variable constant at a time.
Make a list on the board (see below).

Tell students that the first set of combinations of chemicals will involve **sodium bicarbonate**.
Ask: What other chemicals should be added to sodium bicarbonate (one at a time) to investigate the observations made? (Refer to the chemicals written on the board – see above).

Note: When coming up with the list, you will come up with combinations that are the same as previous ones formed. In that case, **CROSS IT OUT ON THE BOARD,** and let students know that they do not have to test it because it would mean repeating an experiment. (Those that are repeated have strikethrough below).

A. **If sodium bicarbonate is the CONSTANT what are the other chemicals that would be the variables?**
   1. $NaHCO_3$ plus water
   2. $NaHCO_3$ plus phenol red solution
   3. $NaHCO_3$ plus $CaCl_2$

B. Continue building the list with $CaCl_2$ as the constant:
   4. $CaCl_2$ plus water
   5. $CaCl_2$ plus phenol red solution
   ~~6.~~ $CaCl_2$ plus $NaHCO_3$ BUT this is already listed in #3.

C. Continue building the list with water (H_2O) as the constant:
   ~~7.~~ H_2O plus $NaHCO_3$ BUT this is already listed in #1.
   ~~8.~~ H_2O plus $CaCl_2$ BUT this is already listed in # 4.
   9. H_2O plus phenol red

Tell students that they have now listed all the experiments for combining two reagents at a time. Tell them that they will also need to do an experiment with a combination of three reagents. Write it on the board.
   10. $NaHCO_3$ plus $CaCl_2$ and water (no phenol red indicator added)

II. Experiment C – Students Make Observations When Reacting 2 Reagents.

Assign every pair one control experiment and hand out a bag of pertinent materials. Each pair should be responsible for only ONE control experiment.

Control Experiments		

Your Notes:

_____

_____

_____

_____

	Reactants (calcium chloride, sodium bicarbonate, phenol red, and water)	**Observations**
Experiment	$CaCl_2$ plus $NaHCO_3$ plus H_2O plus phenol red solution	
Control 1	$NaHCO_3$ plus H_2O	
Control 2	$NaHCO_3$ plus phenol red solution	
Control 3	$NaHCO_3$ plus $CaCl_2$	
Control 4	$CaCl_2$ plus H_2O **Warning – students must use 1 tsp only**	
Control 5	$CaCl_2$ plus phenol red solution **Warning – students must use 1 tsp only**	
Control 6	H_2O plus phenol red	
Control 7	$CaCl_2$ plus $NaHCO_3$ plus H_2O	

Tell students to write their observations and to decide at the end which combination of reagents was responsible for the observations made in the first experiment.

III. Observations and Explanation

1. Have **2 students** from one of the groups who did the experiment with **Control 1** come to the front of the class (or stand where they are). They will:
    a. Demonstrate what they did
    b. Tell the class their observations
2. Ask the class for possible reasons for the observations (see chart below) and then tell them the answers.
3. Repeat with students from **Control 2 and then the remaining student groups.**
4. Write the results on the board so that all students can see them.

Ask students: *Is there any one reagent that is not critical for the reaction to take place?*

Phenol red is not necessary for the reaction to take place, but it shows that the products are more acidic than the reactants.

Explanations for Control Experiments			
	Reactants (calcium chloride, sodium bicarbonate, phenol red, and water)	**Observations**	**Explanation**

Your Notes:

_____

_____

_____

_____

Control 1	$NaHCO_3$ plus H_2O	Solid is slightly soluble; final solution color is cloudy white; solution is cold to touch	The bag feels cold because baking soda absorbs heat when it dissolves in water. This is a physical change and is **Endothermic.**
Control 2	$NaHCO_3$ plus phenol red solution	Solid is slightly soluble; solution color is cloudy purple/pink; solution is cold to touch	Baking soda ($NaHCO_3$) is weakly basic (pH of 8.4), so the solution of phenol red indicator turns purple/ pink.
Control 3	$NaHCO_3$ plus $CaCl_2$	No reaction	None
Control 4	$CaCl_2$ plus H_2O	Solid dissolves into solution and forms a cloudy mixture, then clear; solution becomes warm to touch	Anhydrous calcium chloride gives off heat when it dissolves in water. **It is Exothermic.** This is primarily a chemical change.
Control 5	$CaCl_2$ plus phenol red solution	Solid dissolves; cloudy mixture forms becoming clear; bag becomes warm to touch; color purple/red.	Same as above. Phenol red does not change color.
Control 6	H_2O plus phenol red	Liquids form one solution; slight color change to a paler red. No chemical reaction.	No reaction. We are just diluting the phenol red solution. Phenol red is an acid-base indicator which turns purple in basic solution and yellow in acidic solution.
Control 7	$CaCl_2$ plus $NaHCO_3$ plus H_2O	Bubbles form; fizzing sound is heard; bag expands; bag is cold to touch; solution color is cloudy white.	The bag fills with carbon dioxide gas because the hydrogen ion (formed by ionization of bicarbonate) reacts with remaining bicarbonate ion to give carbon dioxide gas. There will be cold and hot spots, and finally the bag continues to feel cold because heat is being absorbed. See equation below.

Review: *How can you tell when a chemical change has occurred?*

Possibilities include: a gas given off, color change, temperature change, explosion, burning, etc. Tell students what evidence to look for to determine if a chemical reaction occurs: **a color change**, **a gas given off**, **temperature change,** or **the formation of a precipitate.**

Ask students: *What evidence for chemical changes did they observe in today's experiment?*

Answers:

1. A color change.
2. A gas given off.
3. Temperature change.

Clean-up: The team should collect all Ziploc bags and used cups and put them in the trash bag. Make sure the Ziploc bags containing the reaction mixture are sealed before you put them in the trash bag. Then put everything else in the kit box along with the trash bag and return it to the CSEO

IV. BACKGROUND INFORMATION ON CHEMICAL EQUATIONS

The equations for the reactions that occur when anhydrous calcium chloride is added to the sodium bicarbonate solution are given below.

When water is added to calcium chloride, the solid dissolves:

$$CaCl_2\,(s) \rightarrow Ca^{2+}\,(aq) + 2\,Cl^-\,(aq)$$

This reaction is exothermic.

The bicarbonate ion (HCO_3^-) is a weak acid and partially ionizes in solution.

$$HCO_3^-\,(aq) \rightarrow H^+\,(aq) + CO_3^{2-}\,(aq) \qquad (1)$$

Calcium ion (Ca^{2+}) from calcium chloride reacts with sodium bicarbonate to give insoluble calcium carbonate.

$$Ca^{2+}\,(aq) + CO_3^{2-}\,(aq) \leftrightarrow CaCO_3\,(s) \qquad (2)$$

The removal of the carbonate ion from solution shifts the bicarbonate equilibrium (1) to the right, releasing more H^+, which reacts with more HCO_3^- to produce CO_2 gas and H_2O.

$$H^+\,(aq) + HCO_3^-\,(aq) \rightarrow CO_2\,(g) + H_2O\,(l) \qquad (3)$$

The indicator changes color because the carbon dioxide dissolves in water to produce an acidic solution.

$$CO_2\,(g) + H_2O\,(l) \rightarrow H_2CO_3^-\,(aq) \rightarrow H^+\,(aq) + HCO_3^-\,(aq) \qquad (4)$$

Reference: *Fun With Chemistry*, Vol. 1, 2nd ed.; Sarquis M., Sarquis, J., Eds.; Publ. 91-005; Institute for Chemical Education, University of Wisconsin: Madison, 1991; pp 147-153.

Adapted by: Dr. Melvin D. Joesten, Department of Chemistry, Vanderbilt University
Pat Tellinghuisen, Director of VSVS

Your Notes:

_____

_____

_____

_____

Observation Sheet: Experiment and Controls		
	Reactants (calcium chloride, sodium bicarbonate, phenol red, and water)	**Observations**
Experiment	1 tsp $CaCl_2$ plus 1 tsp $NaHCO_3$ plus 15ml H_2O plus phenol red solution	
Control 1	1 tsp $NaHCO_3$ plus 15ml H_2O	
Control 2	1 tsp $NaHCO_3$ plus 15ml phenol red solution	
Control 3	1 tsp $NaHCO_3$ plus 1 tsp $CaCl_2$	
Control 4	1 tsp $CaCl_2$ plus 15ml H_2O	
Control 5	1 tsp $CaCl_2$ plus 15ml phenol red solution	
Control 6	H_2O plus 15ml phenol red	
Control 7	1 tsp $CaCl_2$ plus 1 tsp $NaHCO_3$ plus 15ml H_2O	

Observation Sheet Answer Key: Experiment and Controls		
	Reactants (calcium chloride, sodium bicarbonate, phenol red, and water)	**Observations**
Experiment	$CaCl_2$ plus $NaHCO_3$ plus H_2O plus phenol red solution	No reaction between solids; solution is cold; solution may be warm in some spots; solution color changes from red to yellow; gas and bubbles are given off
Control 1	$NaHCO_3$ plus H_2O	Solid is slightly soluble; final solution color is cloudy white; solution is cold to touch
Control 2	$NaHCO_3$ plus phenol red solution	Solid is slightly soluble; solution color is cloudy purple/pink; solution is cold to touch
Control 3	$NaHCO_3$ plus $CaCl_2$	No reaction
Control 4	$CaCl_2$ plus H_2O	Solid dissolves into solution and forms a cloudy mixture, then clear; solution becomes warm to touch
Control 5	$CaCl_2$ plus phenol red solution	Solid dissolves; cloudy mixture forms, becoming clear; bag becomes warm to touch; color red or purple/red
Control 6	H_2O plus phenol red	Liquids form one solution; slight color change to a paler red. No chemical reaction
Control 7	$CaCl_2$ plus $NaHCO_3$ plus H_2O	Bubbles form; fizzing sound is heard; bag expands; bag has hot and cold spots and then is cold to touch; solution color is cloudy white

Instruction Sheet

Students work in pairs.

1. Hold the bag upright over the plate.

2. Open the bag while an instructor goes by and adds a teaspoon of calcium chloride.

3. Add the phenol red solution (includes water) to the bag and seal the bag.

4. **Gently** shake the contents of the bag while holding the bag over the plate.

5. Feel the bag (while keeping it upright) and record observations about color changes, temperature changes (is the bag cold or warm or both since there can be localized heating), changes in bag size, any gas given off or foaming.

6. The reaction takes about three to five minutes. During this time the student not holding the bag writes down all observations that the pair has made. Then, the students should switch. One should feel the bag and the other should write observations.

NOTE: There is no danger of the bag exploding if the correct amounts of chemicals are used. Since everything is pre-measured, you should have no problems. In the event one does explode or leak, use paper towels to clean up any mess. If you have followed directions, any spilled liquid will be on the plate, which can be easily wiped up with paper towels. Remember that the chemicals are safe.

7. Brainstorm to determine which reagents caused a certain observation.

8. Look at the chemicals in your plastic bag and identify the experiment you will be doing.

9. Add the chemicals in the amounts written on the observation sheet, and record your results.

10. Explain to the class what happened with your chemicals.