VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
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Chemistry in a Ziploc Bag

2018-2019 VINSE/VSVS Rural

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:

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. VSVS Background Information on Chemical Equations

MATERIALS FOR 1 CLASS

- 15 plates
- 15 1 oz cups marked at the 15 mL level
- 15 Ziploc sandwich bags containing one spoonful of baking soda
- 1 large container for making phenol red solution
- 1 container phenol red powder plus mini scoop
- 20 Ziploc sandwich bags
- 1 16 oz jar $CaCl_2$
- 32 spoons
- 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 binder containing ppt, 1 Observation Sheet and 1 answer sheet

I. Introduction

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

Explain to the students that all the knowledge in science 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.

Learning Goals: To give students the opportunity to record observations during chemical reactions

Write the following chemicals on the board:

sodium bicarbonate $NaHCO_3$, calcium chloride $CaCl_2$, water H_2O, phenol red

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

Tell students what evidence to look for to determine if a chemical reaction occurs: **a color change**, **a gas given off**, **temperature change, formation of a precipitate or a new chemical substance is formed.**

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 a VSVS member 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 wr



Your Notes:

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

1. A color change
2. A gas given off (this is a new substance)
3. Temperature changes
4. A white precipitate that is not obvious until the final mixture is allowed to settle out for some time.

II. Experiment B – Brainstorming To Determine the Roles of the Different Reagents in the Reaction .

Learning Goals: To have students use the scientific method to design an experiment.

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

Write the overall equation on the board:
$2NaHCO_3\ (aq) + CaCl_2(aq) \text{-----> } CaCO_3\ (s) + 2NaCl\ (s) + H_2O(l) + CO_2\ (g)$

For this section, students will brainstorm how to determine the role of each of the chemicals
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 fizzes, and the bag fills up with gas.
4. The mixture turns from red to yellow.

Your Notes:

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Take the students through the steps of a systematically designed procedure to test each observation by taking one reagent (called the CONSTANT) and adding another reagent (called a VARIABLE), one at a time. 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 change only one variable 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 different chemicals can be added to change the experiment?"

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.

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.

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Control Experiments		
	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	

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: What chemicals are responsible for the following

1. **The bag feels cold(er)?** The sodium bicarbonate mixed with water caused the temperature to decrease
2. **The bag feels warm(er)?** The calcium chloride mixed with water caused the temperature to increase
3. **The mixture fizzes, and the bag fills up with gas?** Water, calcium chloride, and sodium bicarbonate are all necessary for this reaction, This is the only experiment that produced a gas plus temperature change. Since no other combinations produced the reaction observed in the Ziploc bag, we can conclude that all three reagents must be present.
4. **The mixture turns from red to yellow?** Phenol red is an indicator which turns red in basic solution and yellow in acidic solution.
   Nothing started bubbling or changing temperature when the phenol red was added.. P.henol red is not necessary for the reaction to take place., but it showed that a chemical reaction had taken place.

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

Your Notes:

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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.

Explanations for Control Experiments

	Reactants (calcium chloride, sodium bicarbonate, phenol red, and water)	**Observations**	**Explanation**
Control 1	$NaHCO_3$ plus H_2O	**$NaHCO_3 \rightarrow Na^+(aq) + HCO_3(aq)$** Solid is slightly soluble; final solution color is cloudy white; solution is colder. Temperature drops about 4° C	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 pink; solution is cold to touch	Color is pinkish because the red is mixing with a white cloudy solution
Control 3	$NaHCO_3$ plus $CaCl_2$	No reaction	None
Control 4	$CaCl_2$ plus H_2O	**$CaCl_2 \rightarrow Ca^{2+}(aq) + 2\ Cl^-(aq)$** Solid dissolves into solution and forms a cloudy solution. Solution is warmer. Temperature increases by about 5°C.	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 is 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. Temperature drops about 4°C	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.

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Clean-up: The VSVS 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 VSVS lab.

IV. VSVS 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.

Sodium bicarbonate solid dissolves in water and separates into the 2 different ions: This is a physical change.

$$NaHCO_3 \rightarrow Na^+(aq) + HCO_3\,(aq)$$

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

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

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

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

This reaction is exothermic, and is actually a chemical change. Anhydrous calcium chloride rehydrates and makes strong bonds with water. If a solution of calcium chloride and water is allowed to evaporate, the recovered compound is not chemically the same as the initial anhydrous calcium chloride

The calcium ion (Ca^{2+}) reacts with the bicarbonate ion (HCO_3^-) to form insoluble calcium carbonate and hydrogen ion (H^+).

$$Ca^{2+}\,(aq) + HCO_3^-\,(aq) \rightarrow CaCO_3\,(s) + H^+\,(aq)$$

If the products in the bag are left to settle, there will be a white precipitate evident (this is a new product).

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:

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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 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
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 a VSVS member 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 the students have followed 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.

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.