VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
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Evidence of a Chemical Reaction
Fall 2012

Goal: To show students evidence of a chemical change.
Fits TN standards for Grade 8

Lesson Outline
I. Introduction
   Question students about the difference between physical and chemical change. Explain what constitutes evidence of chemical reactions.

II. Safety Concerns
   Discuss safety issues. Demonstrate how students will use the small dispensing bottles and the 24-well culture plate.

III. Determining if a Chemical Change has Occurred
   Tell students to follow the instructions on the instruction sheet. You will still need to guide them through the procedures, making sure they understand the instructions. Discuss results with students after they finish each row. Chemical equations for Rows A, B, C are given.
   Row A: Chemical Reactions That Give a Precipitate (solid)
   Do Demonstration. Students should realize that if the solution turns cloudy, a solid (precipitate) is forming.

   Row B: Chemical Reactions That Involve a Color Change
   Do demonstration. Formation of complex ions cause color changes. Ex: Thiocyanate (SCN⁻) anion bonds strongly to the Fe³⁺ ion in solution to give an intense deep red color.

   Row C: Chemical Reactions That Produce a Gas
   Do demonstration. Students look carefully at the bubbles produced in solutions.

IV. Analyzing Results
   Emphasize the chemistry of carbonates and bicarbonates. Students predict the reaction between marble and HCl.

V. Review Questions and Equations for Chemical Reactions

VI. Hand out wallet-sized periodic tables
Materials
34 safety goggles for students and VSVS members (in a separate box)
15 24-well culture plates with lids
15 plastic plates (to catch any spillage from well plates)
1 Demonstration Bag A - contains (1) 2 oz bottle of 0.1 M CaCl₂, (1) 2 oz bottle of 2.5 M Na₂CO₃, (2) 10 oz clear cups
1 Demonstration Bag B – contains (1) 2 oz bottle of 0.05 M Na₂S₂O₃, (1) 2 oz bottle of 0.01 M I₂, (2) 10 oz clear cups
1 Demonstration Bag C - contains (1) 2 oz bottle of 1 M HCl, (1) jar of Na₂CO₃, (1) teaspoon, and (1) 10 oz clear cup
15 ziploc bags containing the following:
   6 plastic droppers (in a Ziploc bag) containing bottles of the following solutions
      1.0 M HCl  hydrochloric acid
      2.5 M Na₂CO₃  sodium carbonate
      0.5 M NaHCO₃  sodium bicarbonate
      0.1 M Cu(NO₃)₂  copper (II) nitrate
      0.1 M Fe(NO₃)₃  iron (III) nitrate
      0.1 M KSCN  potassium thiocyanate
15 small pieces of marble CaCO₃ (in a small bag)
1 binder containing:
   34 Instruction Sheets in sheet protectors (one per student)
   34 Handouts showing washing soda and baking soda boxes
   34 Student observation sheets
1 pencil per student (Students should use their own pencils.)
35 wallet-sized periodic tables (per class)
4 1 oz dropper bottles of each of the following unknowns:
   Unknown A: Na₂CO₃
   Unknown B: CaCl₂
   Unknown C: HCl
   Unknown D: KSCN
   Unknown E: NaHCO₃

While one team member starts the introduction, another should write the following vocabulary words on the board:

physical change  chemical change  chemical reaction  formula
   solution    precipitate    compound    mixture

I. Introduction
Ask students: What is the difference between a physical change and a chemical change?
Be sure to include the following information in the discussion:

- **A physical change** does not change the chemical properties of a substance.
  - No new substance is formed during a physical change.
  - Only the physical properties are changed.
  - Examples of physical changes include changes in the size, shape, or state of matter. For example, ice, liquid water, and steam. In each of these states, water has physically changed (from solid, liquid, gas), but not chemically.

- **A chemical change** does change the chemical properties of a substance.
  - One or more new substances are formed in a chemical change.
  - A chemical change cannot be easily reversed.
Examples include: burning paper, digestion of food, bananas browning

Ask students: How can you tell when a chemical change has occurred? *Some possibilities include: a gas given off, color change, precipitation, explosion, burning, etc.*

Tell students what to look for to determine if a chemical change has occurred:
- When solutions of two compounds are mixed, it is often possible to determine whether or not a chemical reaction has occurred through visual observation.
- Evidence of a chemical change might be a **color change**, a **gas given off** *(it may smell)*, the **formation of a precipitate** *(a new solid)*, or an **energy** *(temperature, light)* change.

Write these observations on the board and share the following explanation with students.

- **A color change** occurs when two solutions are mixed and a new color is produced.
  - BUT, if the color of one solution becomes a paler shade, that change is caused by dilution from the other solution and does not qualify as a color change.
- Bubbles or fizz indicate that a **gas is given off**.
  - BUT, make sure that students understand that the bubbles given off in a soda pop drink is NOT evidence of a chemical change. This is just excess gas that is released when the top is opened. Carbonated beverages contain carbon dioxide gas dissolved under pressure and removing the top lowers the pressure and allows carbon dioxide bubbles to escape.
- **A precipitate** forms when two substances react to give a new solid compound that does not dissolve in water.
  - A precipitate may look like a cloudy solution, fine grains in a solution, a swirl, or a fluffy solid.

**Note:** When two clear solutions are mixed and a white precipitate forms, this whitish color does not count as a color change. The change should be recorded only as the formation of a precipitate.

- **An energy change** can be either a physical or chemical change. These changes will be studied in the Endothermic/Exothermic lesson. A chemical energy change occurs in a lightstick when chemicals mix to produces light. A physical energy change occurs when you freeze water. Energy is removed from water, causing the water to freeze and its temperature to change.

**Important:** Scientists do not rely on just visual observations to determine if a chemical or physical change has occurred. The only real evidence is the formation of new substances, with different chemical formulas from the reactants.

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II. Safety Concerns

- Tell students they must put on safety goggles before mixing any solutions.
- If anyone gets any of the chemicals on their skin or in their eyes, they should flush immediately with water. Although the solutions are dilute, they could still cause eye damage, especially the 1.0 M HCl.
- Emphasize to students how important it is for them to follow directions.

Organize students in pairs and distribute the following materials to each pair of students:
- 2 safety goggles
- 1 24-well culture plate
- 1 plastic plate
- 1 Ziploc bag containing 6 dropper bottles of solutions
- 2 Instruction Sheets
- 2 Chemical Reactions Observation Sheets

- VSVS volunteers should put on their safety goggles and keep them on until students are finished mixing chemicals.
- Have students look at the 24-well plate and the instructions at the top of the Chemical Reactions Lab Sheet.
- Show students how to find the letters A, B, C, D as well as the numbers 1 - 6 on the 24-well plate. (Letters are imprinted in the plastic along the right side; numbers are imprinted across the top and the bottom. These are tiny and may be difficult to see.)
- Show students how to match the grid on the lab sheet to the 24-well plate. Tell students to place the 24-well plate on the plastic plate.

Give the following instructions to the students:
1. The formulas of the compounds being used in a reaction are listed on the observation sheet. The labels on the dropper bottles list both the name and formula of the compounds. Show students how to be careful when matching the formulas (some of the formulas are very similar).

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2. Show students one of the bottles and demonstrate how to get drops out of the bottle. Dropper bottles are easy to use. Apply slow, gentle pressure. Do not remove the red cap from a bottle until it is to be used. Put the cap back on the bottle immediately after use.

When using two solutions, put a squirt of the first solution in the correct well so that it is one-fourth full (we do not want students to spend time counting drops). Then add one squirt of the second solution. The well should now be half full.

3. Tell students they will perform the reactions for one row only, then stop and discuss the results with the VSVS members. Tell the partners to take turns doing the experiments as they follow the grid on the lab sheet. Both students record their observations on the lab sheet. Students can record NR if No Reaction occurs. Otherwise, they will record color change, gas given off, or precipitate formed.

4. **Tell students to follow the instructions on the instruction sheet for mixing solutions.** (The instruction sheet lists the same directions as are given below.)

### III. Determining If a Chemical Change Has Occurred

**Note:** VSVS volunteers need to monitor the students closely to be sure contamination does not occur. Ensure that students use the correct bottle.

Stop and discuss results with students after each row. This is preferable to waiting until students finish all of the experiment since some will finish very quickly and then be bored waiting for others to catch up.

One team member should draw a picture of the well plate on the board with all of the rows labeled. Write on this when discussing the results with the students.

The beginning of each reaction is given on the student observation sheet. Students and VSVSers should complete each equation on the board after the reactions in each row are completed.
A. Chemical Reactions that Give Precipitates - Row A

Demonstration: Show students what a precipitate looks like by doing the following demonstration.

- Take the demonstration bag marked ROW A. Remove the 2 oz bottles of solutions and the two 10 oz clear cups. Empty each 2 oz bottles into separate cups. Hold the two cups up so the students can see what happens, and then pour one solution into the other. A white solid (precipitate) forms. Point this out as an example of a chemical reaction in which a precipitate forms to the students.
- Tell students to use the grid on the lab sheet to perform the experiments in Row A.

Note: For each activity DO NOT record the results until the students have completed the experiments for the row since they may wait to copy the answers from the board.

Review and Equations:

- Ask students what evidence indicated that a chemical reaction occurred.
  - A precipitate formed in A1 and A2.
- Put the results on the board. A1: precipitate A2: precipitate
- Write the following equations on the board:

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\text{Demo: } \text{CaCl}_2 (aq) + \text{Na}_2\text{CO}_3 (aq) \rightarrow \text{CaCO}_3 (s) + 2 \text{NaCl} (aq)

A1: \quad 2 \text{Fe(NO}_3\text{)}_3 (aq) + 3 \text{Na}_2\text{CO}_3 (aq) \rightarrow \text{Fe}_2(\text{CO}_3)_3 (s) + 6 \text{NaNO}_3 (aq)

A2: \quad \text{Cu(NO}_3\text{)}_2 (aq) + \text{Na}_2\text{CO}_3 (aq) \rightarrow \text{CuCO}_3 (s) + 2 \text{NaNO}_3 (aq)
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B. Chemical Reactions that Involve a Color Change - Row B

Demonstration: Show students what a color change looks like by doing the following demonstration.

- Take the demonstration bag marked ROW B. Remove the 2 oz bottles of solutions and the two 10 clear plastic cups. Empty each 2 oz bottles into separate cups. Hold the two clear containers up, and tell students to notice that one is a clear colorless solution, and the other is a clear, brown solution. Pour the colorless solution into the brown solution, and ask students to describe what happens. The brown solution turns colorless, but it is still clear (i.e. no precipitation). Explain to students that a chemical reaction has taken place because the brown solution turned colorless upon addition of the clear solution.
- Tell students to use the grid on the lab sheet to perform the experiments in Row B.

**Background for VSVS Members Only:** This is an oxidation-reduction reaction in which iodine is reduced to iodide ion and thiosulfate ion, S\(_2\)O\(_4\)\(^2-\) is oxidized to tetrathionate ion, S\(_4\)O\(_6\)\(^2-\).

Review and Equations:

- Ask students what evidence indicated that a chemical reaction occurred.
  - A color change occurred.
- Put the results on the board. **B1:** *color change to deep red*  **B2:** *color change to pale green.*
- Write the following equations on the board:
  - Demo: \(I_2\text{(aq)} + 2\text{Na}_2\text{S}_2\text{O}_3\text{(aq)} \rightarrow 2\text{NaI(aq)} + \text{Na}_2\text{S}_4\text{O}_6\text{(aq)}\)
  - B1: \(\text{Fe(NO}_3\text{)_3(aq)} + \text{KSCN(aq)} \rightarrow \text{Fe(SCN)(NO}_3\text{)_2(aq)} + \text{KNO}_3\text{(aq)}\)
  - B2: \(\text{Cu(NO}_3\text{)_2(aq)} + \text{KSCN(aq)} \rightarrow \text{Cu(SCN)(NO}_3\text{)_2(aq)} + \text{KNO}_3\text{(aq)}\)
  - pale green color

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C. Chemical Reactions that Produce a Gas - Row C

**Background for VSVS Members Only:** Color changes with metal ion solutions are caused by the formation of complex ions. In the present case, the SCN⁻ (thiocyanate) anion bonds strongly to the Fe³⁺ (iron) ion in solution to give an intense deep red color. The SCN⁻ anion also bonds to Cu(II) (copper) ion but not as strongly, so more SCN⁻ has to be added before the pale green color is seen.

**Demonstration:** Show students what a chemical change that produces a gas looks like by performing the demonstration first.

- Take the demonstration bag marked ROW C. Hold the cup up and ask students to watch very carefully what happens. Put 1 teaspoon of the solid (Na₂CO₃) into the cup and empty the 2 oz bottle (HCl) into it. Ask students to describe what happens.
  - A bubbling up (slight foaming) which quickly subsides indicates a gas is given off. Tell students to watch very carefully for bubbles of gas when they are doing Row C because they may be difficult to see.
- Tell students to use the grid on the lab sheet to perform all the experiments in Row C.

**Review and Equations:**

- Ask students what evidence indicated that a chemical reaction occurred.
  - *Bubbles/gas was given off.*
- Put the results on the board. **C1: bubbles/gas C2: bubbles/gas**

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Write the following equations on the board:

Demo: \( Na_2CO_3 (s) + 2HCl (aq) \rightarrow 2NaCl (aq) + CO_2 (g) + H_2O (l) \)

C1: \( NaHCO_3 (aq) + HCl (aq) \rightarrow NaCl (aq) + CO_2 (g) + H_2O (l) \)

C2: \( Na_2CO_3 (aq) + 2HCl (aq) \rightarrow 2NaCl (aq) + CO_2 (g) + H_2O (l) \)

IV. Analyzing Results

Hand out the copies of washing soda and baking soda boxes.

Carbonates:
- Write \( CO_3^{2-} \) on the board and tell students that formulas that include “\( CO_3 \)” as part of the formula are called carbonates. The carbonate ion has 2 negative charges on it.
- One form of carbonate, sodium carbonate is commonly referred to as "washing soda." It is part of many laundry detergents and dish washing detergents.
- Tell students to look at the ingredients of the copy of a washing soda box. Sodium carbonate is listed as an ingredient.

Bicarbonates:
- Write \( HCO_3^- \) on the board and tell students that formulas that include “\( HCO_3 \)” as part of the formula are called bicarbonates. The bicarbonate ion has 1 negative charge associated with it.
- A common source of bicarbonate is baking soda, whose scientific name is sodium bicarbonate. Sodium bicarbonate is used for baking and as a deodorizer. Tell students to look at the ingredient label on baking soda and notice it says sodium bicarbonate.

Reactions of Carbonates and Bicarbonates:
- Ask students to look at each box in row C and circle the formulas that have “\( CO_3 \)” or “\( HCO_3 \)” as part of the formula.
- Write HCl on the board.
  - Tell students that HCl is an acid called hydrochloric acid.
  - Tell students to put boxes around all the HCl’s in Row C.
- Ask students what happened in row C when an acid was added to a carbonate or bicarbonate. A gas was given off.
- Ask students if they have ever made a “volcano” at home or at school. Ask students if they remembered what they added to make the “lava”. Most likely, they used vinegar and baking soda. Vinegar is an acid, and when added to baking soda (sodium bicarbonate), it bubbles as it releases a gas.

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- Ask students what happens when you add an acid to carbonate or bicarbonate. *When an acid is added to a carbonate or bicarbonate a chemical reaction occurs.* This is evidenced by the fact that a gas is given off.
- Tell students that the gas given off in these reactions is carbon dioxide.

**Identifying Carbonates Using Chemical Reactions:**
- Tell students that chalk, limestone and marble are all calcium carbonate. If the formula for calcium carbonate is \( \text{CaCO}_3 \), what might happen if an acid (HCl) is added to marble? *It will bubble (give off a gas).*
- Write the first half of the equation, \( \text{CaCO}_3 (s) + \text{HCl (aq)} \rightarrow \) on the board, and ask students to hypothesize what will happen, and what the products will be.
  - *The gas will be \( \text{CO}_2 \).*
- The full equation is: \( \text{CaCO}_3 (s) + 2\text{HCl (aq)} \rightarrow \text{CaCl}_2 (aq) + \text{CO}_2 (g) + \text{H}_2\text{O (l)} \)
- Have VSVS members hand out a piece of marble to each pair of students. Tell students that they are going to test their hypothesis to see if the marble will bubble when HCl is added.
- Have students add the marble to C5 and to squirt some HCl into the well. Ask students what happened. Was their hypothesis correct? *Yes, it should bubble when HCl is added.*
- Tell students that many statues are made of limestone and marble. Ask students what they think happens to statues when acid rain falls on them. *The carbonate in the statue reacts with acid liberating a gas and causing the statue to decompose.*

**Background Information (in case students ask about acid rain):** Acid rain is caused by the presence of varying amounts of sulfuric acid and nitric acid. Fossil fuels, particularly coal and oil, contain sulfur as an impurity. When fossil fuels are burned, the sulfur combines with oxygen to form sulfur oxides that are gases released into the air. When it rains, the water reacts with these gases to form sulfuric acid. When vehicles burn gasoline or diesel fuel, nitrogen oxides are emitted into the air, and these react with water to produce nitric acid. The amount of sulfuric acid and nitric acid in acid rain depends on the location. The acid rain in Nashville is primarily caused by nitric acid from the high density of vehicles, while the acidity of rain in industrialized areas will be caused by the presence of both sulfuric and nitric acids. As a result of the Clean Air Act, industrial and power plants are emitting much lower amounts of sulfur oxides. However, the emission of nitric oxides from vehicle exhausts is still a problem.

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VI. Review Questions
Ask students:
- What is a physical change?
- What is a chemical change?
- How do we know when a chemical change has occurred? (answer on p. 3)

VII. Clean-up
- Have students put the dropper bottles back in the ziplock bag. Make sure all red lids are on dropper bottles and that the bottles are all upright. Leaks make for nasty clean-up tasks.
- Collect the ziploc bags and the goggles.
- Place the lids on the 24-well plates and carefully put them in the Rubbermaid container. Place the lid on the Rubbermaid container and put it in the bottom of the box. (If you can rinse them out at the school, do so, PLEASE)
- Place the ziploc bags and other materials in the box.
- Collect all instructions sheets in sheet protectors and put them in the box.

Give each student a wallet-sized Periodic Table.

Chemical Equations for Chemical Reactions in this Lesson
Abbreviations:  s = solid, aq = aqueous, g = gas, l = liquid, NR = no reaction

Row A (precipitate)
Demo: CaCl₂ (aq) + Na₂CO₃ (aq) → CaCO₃ (s) + 2 NaCl (aq)
A1: 2 Fe(NO₃)₃ (aq) + 3 Na₂CO₃ (aq) → Fe₂(CO₃)₃ (s) + 6 NaNO₃ (aq)
A2: Cu(NO₃)₂ (aq) + Na₂CO₃ (aq) → CuCO₃ (s) + 2 NaNO₃ (aq)

Row B: (color change)
Demo: I₂ (aq) + 2 Na₂S₂O₃ (aq) → 2 NaI (aq) + Na₂S₄O₆ (aq)
B1: Fe(NO₃)₃ (aq) + KSCN (aq) → Fe(SCN)(NO₃)₂ (aq) + KNO₃ (aq)
B2: Cu(NO₃)₂ (aq) + KSCN (aq) → Cu(SCN)(NO₃) (aq) + KNO₃ (aq)

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Row C:

Demo Na₂CO₃ (s) + 2HCl (aq) → 2NaCl (aq) + CO₂ (g) + H₂O (l)

C1: NaHCO₃ (aq) + HCl (aq) → NaCl (aq) + CO₂ (g) + H₂O (l)

C2: Na₂CO₃ (aq) + 2HCl (aq) → 2NaCl (aq) + CO₂ (g) + H₂O (l)

C5: CaCO₃ (s) + 2HCl (aq) → CaCl₂ (aq) + CO₂ (g) + H₂O (l)

Add unknowns as extension

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