VOLUNTEER INFORMATION

Team Member Contact Information

Name: ___________________________________________ Phone Number: ___________________________________________

Name: ___________________________________________ Phone Number: ___________________________________________

Name: ___________________________________________ Phone Number: ___________________________________________

Name: ___________________________________________ Phone Number: ___________________________________________

Name: ___________________________________________ Phone Number: ___________________________________________

Name: ___________________________________________ Phone Number: ___________________________________________

Teacher/School Contact Information

School Name: ___________________________________________ Time in Classroom: _______________________

Teacher’s Name: _______________________________________ Phone Number: __________________________

VSVS INFORMATION

VSVS Director: Pat Tellinghuisen 615-343-4379 (W), 615-297-5809 (H)
patricia.c.tellinghuisen@vanderbilt.edu

VSVS Office: Stevenson Center 5234

Co-Presidents: Helen Zhou  helen.zhou@vanderbilt.edu
Sparsh Gupta  sparsh.gupta@vanderbilt.edu

Secretary: Evan Mercer  evan.t.mercer@vanderbilt.edu

Vanderbilt Protection of Minors Policy: As required by the Protection of Minors Policy, VSVS must keep track of the attendance – who goes out when and where.
https://www4.vanderbilt.edu/riskmanagement/Policy_FINAL%20-%20risk%20management%20v2.pdf

Before You Go:

- Watch the videos of the lessons you are doing. The lessons are online at:
  http://studentorgs.vanderbilt.edu/vsvs/
- Email the teacher prior to the first lesson.
- Set a deadline time for your team. This means if a team member doesn’t show up by this time, you will have to leave them behind to get to the school on time.
- Don’t drop out from your group. If you have problems, email Pat or one of the co-presidents, and we will work to help you. Don’t let down the kids or the group!
- If your group has any problems, let us know ASAP.

Picking up the Kit:

- Kits are picked up and dropped off in the VSVS Lab, Stevenson Center 5234.
- The VSVS Lab is open 8:30am – 4:00pm (earlier if you need dry ice or liquid N₂).
- Assign at least one member of your team to pick up the kit each week.
- Kits should be picked up at least 30 minutes before your classroom time.
- If you are scheduled to teach at 8am, pick up the kit the day before or make arrangements to meet at the lab at 7:30am
- There are two 20 minute parking spots in the loading dock behind Stevenson Center. Please do not use the handicap or Medical Dean’s spaces – you will get a ticket.

While you’re there – Just relax and have fun!
### SEPTEMBER

<table>
<thead>
<tr>
<th>SUN</th>
<th>MON</th>
<th>TUES</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
</tr>
</tbody>
</table>

- Team Leader Training
- Team Training (Lessons 2-4)

### OCTOBER

<table>
<thead>
<tr>
<th>SUN</th>
<th>MON</th>
<th>TUES</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>29</td>
<td>30</td>
<td>31</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

- Class Visits: Week 1 Lessons
- Class Visits: Week 2 Lessons
- Class Visits: Week 3 Lessons
- Class Visits: Week 4 Lessons

### NOVEMBER

<table>
<thead>
<tr>
<th>SUN</th>
<th>MON</th>
<th>TUES</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

- Make-up Week

### CLASSROOM ETIQUETTE

Follow Metro Schools’ Dress Code!
http://www.mnps.org/policies-and-procedures/2016/7/19/sp-6114-dress-code-personal-appearance?rq=standard%20attire

- No miniskirts, shorts, tights, or tank tops.
- Tuck in shirts if you can.
- Please dress appropriately.
But what do I do in a classroom?
The key to controlling a classroom is good preparation. Kids act out when they are not engaged, so you and your team need to engage the entire classroom of students in order to promote positive behavior. Remember, the goal is to excite kids about science and college, not to teach them the science standard backwards and forwards. There are a few steps you can take to engage the entire classroom.

1. **Prepare your class.** There’s no reason to leave the students in suspense as to what is coming. Open each lesson with a two sentence outline of the day. “Today we will be talking about comets. We will discuss how comets form around the sun and the orbits they take, and then we will build our own comets here in the classroom.”

2. **Plan ahead.** Know your lesson, your transitions, and your questions. If you need something written on the board, write it while another team member is speaking. If you need materials from the kit, prepare them while another team member is leading an activity. If you don’t leave gaps in the activity, kids won’t have time to act out.

3. **Ask questions often and well.** Leave 7 seconds after asking the questions before calling on a student to answer. Pick different kids to ask and answer questions, not just the student whose hand goes up first. Know your questions (and potential student answers) before you ask them. When students give correct answers, tell them and reinforce their engagement with the lesson.

4. **Be flexible.** We’re there to have fun with science. If something is going wrong with the experiment kit, or if the students are responding incredibly well to one aspect of the lesson and terribly to another, it is okay to adapt. This manual is a resource, not a bible. With that said, prepare yourself for these lessons. You can’t be flexible unless you know the original lesson well enough to properly modify it on the spot.

**DIRECTIONS TO SCHOOLS**

**H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD**
HG Hill School will be on the right across the railroad lines.

**HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE**
The parking lot on the left to the Johnston Ave.

**JOHN EARLY MIDDLE SCHOOL: 1000 CASS STREET**
Going down the Cass Street, the school is on the right.

**J.T. MOORE MIDDLE SCHOOL: 4425 GRANNY WHITE PIKE**
From Lone Oak, the parking lot is on the right, and the entrance into the school faces Lone Oak, but is closer to Granny White.

**MEIGS MIDDLE SCHOOL: 417 RAMSEY STREET**
Going down Ramsey Street, Meigs is on the left.

**ROSE PARK MAGNET SCHOOL: 1025 9th AVE SOUTH**
The school is located on the left and the parking is opposite the school, or behind it (preferred).

**WEST END MIDDLE SCHOOL: 3529 WEST END AVE**
Parking is beside the soccer field, or anywhere you can find a place. Enter through the side door.

**MARGARET ALLEN MIDDLE SCHOOL: 500 SPENCE LANE**

**EAST NASHVILLE MAGNET SCHOOL: 2000 GREENWOOD STREET**
The school also has the name Bailey Junior High etched in stone!
Acids and Bases Mini Lesson

Fall 2017

GOAL: To introduce students to acids and bases.

Fits Tn State standards:
- GLE 0507.9.1Observe and measure the simple chemical properties of common substances
- GLE 0807.9.2 Explain that matter has properties that are determined by the structure and arrangements of its atoms
- GLE 0807.9.9 Explain the difference between acids and bases

VSVSer LESSON OUTLINE

___ I. Introduction
   - Demonstrate how to test for acidity/basicity using litmus paper in vinegar, water, and ammonia.

___ II. Discussion of Acids and Bases
   - Give some examples of acids and bases and introduce the pH scale.

___ III. Testing Acids and Bases
   - Students work in pairs to test the pH of several household chemicals using universal indicator paper. Record the results on the board after each chemical is tested.

___ IV. Neutralization of an Acid with a Base
   - Students work in pairs to determine how many drops of base are needed to neutralize an acid.

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/

USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. In the car ride, 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) What is litmus paper used for?
2) What will an acid do to the blue litmus paper/the red litmus paper?
3) What will a base do to the blue litmus paper/the red litmus paper?
4) What will a neutral solution do to the blue litmus paper/the red litmus paper? What is an indicator used for and where does it change colors? How does the universal pH indicator work?
5) An acidic solution is higher pH or lower pH? A basic solution?
6) How can we treat stomach indigestion? How does it work?
7) Are the foods generally going to be more acidic or basic?
8) Are the cleaners generally going to be more acidic or basic?

2. Use these fun facts during the lesson:

Naturally occurring acids:
- One naturally occurring acid is ascorbic acid, found in citrus fruits, which is more commonly known as vitamin C. Vitamin C is a crucial part of the human diet because without it we can get a disease called scurvy.
- Lactic acid in yogurt aids in the fermentation process.
- Carbonic acid present in many soft drinks (sodas): The bubbles and fizz that you see and hear is carbonic acid turning into carbon dioxide gas and escaping the liquid. The acid in soda can erode away the enamel in your teeth and leave them vulnerable to cavities.
• Old jewelry with an unattractive film on it can be dipped briefly in acid to clean it and return its metallic sheen. The acid eats away at the film on the outside to expose the clean, shiny layer underneath it. In fact, if you leave a dirty penny in soda or vinegar for a while, you might be able to clean off some of the film on the outside of it.

• Fluoroantimonic acid (H2FSbF6) is the strongest acid. It is a superacid, which means it is more acidic than 100% sulfuric acid.

• Proteins are made of acids called amino acids.

Naturally occurring bases:
• Seawater is slightly basic because of dissolved minerals.
• Bleach is a common base used in cleaning.
• Calcium carbonate and other carbonate minerals in limestone rock are basic.
• Bases can dissolve fats and oils so they are good on grease, which is why they are used in soap. However, bases can also remove the fats and oils in and on your skin. This is why your hands dry out after you’ve done the dishes for a long time.

• An amphiprotic substance is one that can act as both an acid and a base.

Write the following vocabulary words on the board:
  acid, base, neutral, litmus paper, indicator, universal indicator

Unpacking the Kit – What you will need for each section:
VSVSers do this while 1 person is giving the Introduction. Note that students are put into pairs and should have their pencils ready.

For Part I Introductory Demonstration:
3 10 oz. clear plastic glasses
1 4 oz. bottle of vinegar, 1 4 oz. bottle of water , 1 4 oz. bottle of dilute (25%) clear ammonia
3 strips red litmus paper, 3 strips blue litmus paper
16 Indicator handouts
32 Instruction/observation sheets

For Part III: Testing Acids and Bases
16 tweezers
16 containers of pHhydrion paper
16 24-well trays
8 plastic bags containing a numbered dropper bottle of each of the following household liquids:
  #3, distilled water, #4, rain water, #7 lemon juice, #8, 7-up, #12, laundry detergent

For Part IV: Neutralization of an Acid with a Base
16 dropper bottles containing .1M HCl
16 dropper bottles containing .1M NaOH
8 dropper bottles universal indicator
16 jars half filled with distilled water.
distilled water dropper bottle and well plates from Part II

Your Notes:

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________
I. INTRODUCTORY DEMONSTRATION - DEFINING ACIDS AND BASES

### Learning Goals:
- Students will learn that different solutions can be acidic, basic, or neutral.
- Students will learn characteristics of acid and bases.
- Students will understand how litmus paper can be used to determine whether a solution is acidic, basic, or neutral.

### You will need:
- 3 10 oz. clear plastic glasses
- 1 4 oz. bottle of vinegar
- 1 4 oz. bottle of water
- 1 4 oz. bottle of dilute ammonia
- 3 strips red litmus paper
- 3 strips blue litmus paper

- Have 2 VSVS volunteers hold the 3 clear plastic glasses up so students can see them.
- Tell the students that you have three liquids.
- Pour the contents of the bottle labeled vinegar into the first glass.
- Pour the contents of the bottle labeled water into the second glass.
- Pour the contents of the bottle labeled ammonia into the third glass.
- Have a student describe the three liquids they see.

**Note:** Describe liquids based on visual cues only. Students may assume that all three glasses contain water. At this point that is an appropriate assumption based on visual cues alone. Since the liquids were in different containers, the students may think that the liquids are different.

Ask students if they have ever heard of litmus paper. If so, what is it used for?

Litmus paper is used to test whether something is acidic or basic.

Test each glass of clear liquid by dipping first the red and then the blue litmus paper into the liquid and noting what changes, if any, occur. (Record the changes on the board for students to copy onto their Results sheet.)

**Note:** The vinegar should turn the blue litmus paper red; the water should not change the color of either paper, and the ammonia should turn red litmus paper blue.

Explain to students: In this experiment, the liquids turned the litmus paper different colors because one is an acid, one is a base, and one is a neutral (neither an acid nor a base). Litmus paper is an indicator which can identify whether a substance is an acid or a base.

Ask students if they can name any other indicators.

Students may be familiar with bromothymol blue, universal indicator, or phenol red. These are chemical indicators. Red cabbage juice extract is a natural indicator. Many other plant extracts also change color in basic or acidic solutions.

Tell students that:

**Your Notes:**
**Indicators** are substances that change colors when mixed with an acid or base. Indicators are used by scientists to identify what the pH of a substance is. Tell students to look at the Indicator handout. Point out a few examples of how they can be useful in different ways.

For example, *litmus* can tell us if something is either a base or an acid.

- Methyl orange indicator changes color at pH 3/4. It is red below pH 4 and yellow above pH 4.
- Universal indicator has a large number of color changes at different pH’s and can more precisely tell us what the pH of a solution is.

II. DISCUSSION OF ACIDS AND BASES

<table>
<thead>
<tr>
<th>Learning Goals:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Students understand how to use pH paper to determine if a solution is acidic, basic, or neutral.</td>
</tr>
<tr>
<td>- Students can confidently read a pH scale to determine level of acidity/basicity.</td>
</tr>
</tbody>
</table>

Ask: *What do you know about acids?* (Ask students to name some acids.)

Responses may include references to battery acid, acid indigestion, stomach acid, acid rain, citric acid, and chemicals in a lab.

Ask: *What do you know about bases?* (Ask students to name some bases.)

Most students know less about bases than acids. Responses may include lye, detergents.

EXPLAIN ACIDS AND BASES USING SOME OF THE FOLLOWING INFORMATION:

(Note: Feel free to add other appropriate information but keep this discussion brief.)

**ACIDS**

- Natural acids in food give foods a sour, sharp flavor.
- Strong acids can burn your skin.
- Many acids are corrosive. They eat away metals and other substances.
- Some acids can be helpful. The acid in your stomach aids in digestion.
- Two acids (sulfuric acid and nitric acid) cause damage in acid rain.

**BASES**

- Bases taste bitter and feel slippery.
- Some bases are used to settle upset stomachs.
- Detergents and many cleaning solutions are basic.
- Strong bases can burn the skin.

Ask the students: *Has anyone heard of the pH scale?*

The pH scale was designed to measure the acidity or basicity of solutions.

On the pH scale, lower numbers are more acidic solution and higher numbers are more basic. Most household chemicals have pH’s between pH 0 and 14, but more concentrated solutions of acids and bases exist that go beyond either end of this scale.

Like the Richter scale used to measure the extent of ground movement in earthquakes, the pH scale is a logarithmic scale. This means that a substance at pH 6 is ten times more acidic than a substance of pH 7, a substance at pH 5 is one hundred times (10x10) more acidic than a substance of pH 7, a substance at pH4 is one thousand times (10x10x10) more acidic than a substance of pH 7, and so on.

Your Notes:
III. TESTING ACIDS AND BASES

Learning Goals:
- Students become familiar with universal indicator as a visual method of measuring and monitoring a solution’s pH.
- Students understand that an acid can be neutralized by a base and a base can be neutralized by an acid.

Ask: How can scientists tell which solutions are acidic or basic?
   Based on the first experiment, some students may be able to reason that scientists could use different shades of color of litmus to tell how acidic or basic a solution is.

Ask: When red litmus paper is used as the indicator, what color do the basic solutions turn it? Blue
Ask: When blue litmus paper is used as the indicator, what color do the acidic solutions turn it? Red

Tell students that they will use universal indicator paper which changes many colors depending on the pH of the solution.

TESTING THE ACIDITY/BASICITY OF HOUSEHOLD ITEM

- Organize the class into 16 pairs. Groups will be made of two pairs.
- Students will test several household items to determine if they are acidic, basic, or neutral
- Distribute the following materials to each group (there are enough materials for 16 pairs – the dropper bottles will be shared between two pairs):
  1 well trays
  1 containers pHydron papers (at least 15 in each)
  1 Instruction/observation sheets with the well-plate diagram per group
  1 pair tweezers
  1 result sheets with chart per student
  1 bag containing household liquids (to be shared between two pairs)

Management tip – do one household chemical at a time, put the results on the board, and then go to the next chemical.

VSVS member: Put the Testing Household Items chart (below) on the board.

<table>
<thead>
<tr>
<th>Item</th>
<th>Result of Test</th>
<th>pH Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>acid base or neutral</td>
<td>What is the pH number?</td>
</tr>
<tr>
<td>3. distilled water</td>
<td>acid base or neutral</td>
<td></td>
</tr>
<tr>
<td>4. rain water</td>
<td>acid base or neutral</td>
<td></td>
</tr>
<tr>
<td>#7, lemon juice</td>
<td>acid base or neutral</td>
<td></td>
</tr>
<tr>
<td>8. 7-up</td>
<td>acid base or neutral</td>
<td></td>
</tr>
<tr>
<td>12. laundry detergent</td>
<td>acid base or neutral</td>
<td></td>
</tr>
</tbody>
</table>

Your Notes:
Tell the students to:

- Arrange the bottles of household chemicals in numerical order.
- Students place their well-plate on the observation sheet on top of the diagram.
- Squirt a small amount of liquid from the first dropper bottle into the first well and test its acidity/basicity by dipping a piece of pHydrion paper into the liquid in the well. Hold the paper with tweezers.
- Place the pHydrion paper in the labeled rectangle.
- Compare the color of the pH paper directly after the test to the colors on the vial and record the corresponding pH number on the line.
- Circle the color change on the results sheet, circle whether the substance is an acid, base, or neutral, and fill in the pH number.
- Report findings to the VSVS student who is completing the chart on the board. VSVSers need to make sure that students are getting the correct answers.
- Repeat this with all the liquids.

Ask students (have them fill in the answers on their results sheet):

- Are the foods that we have tested acidic or basic? Mostly acidic.
- Are the cleaners that we have tested acidic or basic? Basic
- Is there any difference in acidity of distilled water and rain water? Rain water usually tests slightly acidic because of dissolved carbon dioxide. Pollutants from burning fossil fuels such as sulfur oxides and nitrogen oxides can cause the rain water to be even more acidic (hence acid rain).
- Distilled water should be neutral.

**Testing Household Items - Answers**

<table>
<thead>
<tr>
<th>Item</th>
<th>Result of Test</th>
<th>pH Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. distilled water</td>
<td>Neutral</td>
<td>7</td>
</tr>
<tr>
<td>4. rain water</td>
<td>acid</td>
<td>5-6</td>
</tr>
<tr>
<td>7. lemon juice</td>
<td>acid</td>
<td>3</td>
</tr>
<tr>
<td>8. 7-up</td>
<td>acid</td>
<td>3-4</td>
</tr>
<tr>
<td>12. laundry detergent</td>
<td>base</td>
<td>12</td>
</tr>
</tbody>
</table>

**IV. NEUTRALIZATION OF AN ACID WITH A BASE**

Ask students if they know what happens when an antacid is taken for an upset stomach.

- The pH of your stomach varies, from 1-2 up to 4-5. When you eat, the stomach releases proteases and hydrochloric acid to aid in digestion. After a high-protein meal, your stomach pH may drop to as low as 1 or 2; however, buffers quickly raise the pH back to 3 or 4. After the meal has been digested, your stomach pH returns to a resting level of about 4 or 5.
- Stomach indigestion is often caused by too much acid in the stomach. An antacid will react with the acid in your stomach and help neutralize it.

Your Notes:

____________________________________________________________________________________
Pass out the 2 jars of distilled water, 1 dropper bottle of .1M HCl and .1M NaOH to each pair, and 1 universal indicator bottle to each group of 2 pairs. Pairs will share the universal indicator.

Tell students to:

1. Put a squirt of the .1M HCl in first well on the bottom row (D1) as indicated on the observation sheet. Add a few drops of the universal indicator and note the color.
2. Repeat with a squirt of .1M NaOH in D2.
3. Repeat with a squirt of distilled water in D3.
4. Add a squirt of Universal Indicator to the 2 jars of distilled water. Note the color.
5. Add 20 drops (counting carefully) of .1M HCl into one of the jars. Note the color. What is the pH?
6. **Add .1M NaOH one drop at a time, counting the drops added, and observing the color change in the universal indicator.** Stop when the universal indicator color is that of neutral pH7. Record the # drops needed to neutralize the acid.
7. Add 20 drops of .1M NaOH to the other jar and note the color. What is the pH?
8. **Add .1M HCl one drop at a time, counting the drops added, and observing the color change in the universal indicator.** Stop when the universal indicator color is that of neutral pH7. Record the # drops needed to neutralize the base.

**Optional Information**

**How is litmus paper made?**

Litmus paper is simply paper that has been infused with lichens. Ask students if they have seen lichens growing. They may not be aware that lichens are very common and can be found growing on rocks, trees, walls and in soil just about anywhere in the world. They have a natural ability to change color depending on the conditions they are growing in. Several varieties of lichens are used to make litmus paper.

**How is Universal indicator made?**

It is a combination of several chemical indicators so that there is a continuous change of colors over the pH range of 0-14. Universal Indicator can also be impregnated into paper to be used as the pHydrion paper. Red cabbage extract has a similar range of colors due to the natural compound anthocyanin. You can make red cabbage indicator paper at home using red cabbage extract (by boiling red cabbage in water) and soaking coffee filter paper in it.


Lesson written by Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Courtney Luckabaugh, VSVS Lab Manager, Vanderbilt University

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Acids and Bases Instruction Sheet

Place well plates on the picture below. Make sure that you can see the numbers in the wells.

2. After you have tested the household chemical with the pH paper, place the pieces of paper in the box below. Determine if it is an acid, base or neutral liquid, and circle the correct answer. Record the actual pH number for each chemical on the line provided.

detergent

acid               acid                          acid    acid                acid
base               base                          base   base                                base
neutral                neutral                          neutral                       neutral                              neutral

pH ______    pH ______ pH ______  pH ______                   pH ______

Observations from Introductory Demonstration I (copy from the board)

Are the foods that we have tested acidic or basic?  ___________________
Are the cleaners that we have tested acidic or basic?  ___________________
Is there any difference in acidity of distilled water and rain water?  ___________________

<table>
<thead>
<tr>
<th></th>
<th>Red litmus turns…</th>
<th>Blue litmus turns…</th>
<th>Is it an acid, base or neutral?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many drops of .1M NaOH did it take to neutralize the 20 drops of .1M HCl? ____________
How many drops of .1M HCl did it take to neutralize the 20 drops of .1M NaOH? ____________
1. Place well plates on the picture below. Make sure that you can see the numbers in the wells.

3  4  7  8  12

After you have tested the household chemical with pH paper, place the pieces of pH paper in the boxes below. Determine if it is an acid, base or neutral liquid, and circle the correct answer. Record the actual pH number for each chemical on the line provided. Record the pH number based on the first color change of the pH paper!!! As it sits, the color of the paper will change.

neutral            acid                acid               acid               base
pH 7               pH 5-6                pH 3                pH 3-4              pH 11

Observations from Introductory Demonstration I (copy from the board)

<table>
<thead>
<tr>
<th></th>
<th>Red litmus turns…</th>
<th>Blue litmus turns…</th>
<th>Is it an acid, base or neutral?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td>red</td>
<td></td>
<td>acid</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td>neutral</td>
</tr>
<tr>
<td>Ammonia</td>
<td>blue</td>
<td></td>
<td>base</td>
</tr>
</tbody>
</table>

Are the **foods** that we have tested acidic or basic? **Mostly Acidic**
Are the **cleaners** that we have tested acidic or basic? **Mostly basic**
Is there any difference in acidity of distilled water and rain water?

Rain water usually tests slightly acidic because of dissolved carbon dioxide. Pollutants from burning fossil fuels such as sulfur oxides and nitrogen oxides can cause the rain water to be even more acidic (hence acid rain).
Distilled water should be neutral.

How many drops of .1M NaOH did it take to neutralize the 20 drops of .1M HCl?
It should take about 20 drops.
Endothermic/Exothermic Reactions
Fall 2017

Goal: To help students understand endothermic and exothermic processes.

TN Curriculum Alignment: GLE 0807.9.3 Interpret data from an investigation to differentiate between physical and chemical changes.

VSVSer Lesson Outline:

_______ I. Introduction
Define endothermic (heat absorbed) and exothermic (heat given off). Students will study examples of both chemical and physical changes that are endothermic or exothermic.

_______ II. Endothermic Processes
Students learn about endothermic processes by adding ammonium nitrate to water and adding sodium bicarbonate solid to citric acid solution.

_______ III. Exothermic Chemical Processes
A. Setting up the HotHands hand warmer – Activity started by students. To be left aside and returned to in part C.
B. Anhydrous calcium chloride mixed with water – Activity done by students. Anhydrous calcium chloride absorbs water to become hydrated calcium chloride, which then dissolves in water.
C. Demonstrate how reactions happen using molecular models. Use the diagrams passed out to class to further explain why some reactions are endothermic or exothermic.
D. Checking the HotHands Hand Warmer – Students make observations. VSVS members explain the chemistry behind the exothermic process.

_______ IV. Review

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM (https://studentorg.vanderbilt.edu/vsvs/lessons/)
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

Unpacking the Kit – What you will need for each section:
One team member should put the following vocabulary words on the board:
endothermic, exothermic, ammonium nitrate, calcium chloride

For Part I. Introduction
32 observation sheets, 16 instruction sheets in sheet protectors

For Part II. Endothermic Processes
A. Endothermic Experiment – Dissolving Ammonium Nitrate in Water
1 cold pack
16 test tube racks - add 3 test tubes to each, 16 thermometers, 8 4 oz jars of ammonium nitrate, 16 white taster spoons, 8 water bottles (shared by pairs)
1 paper towel
Goggles for ALL
1 set of molecular models

Your Notes:
B. Endothermic Experiment #2—Reacting Sodium Bicarbonate with Citric Acid
16 clean test tubes in test tube rack from above, 16 thermometers (from above)
16 2oz bottles citric acid solution, 16 spoons (from above)
8 jars sodium bicarbonate

For Part III. Exothermic Reactions
A. Chemical (HotHands) Hand Warmer
8 HotHands hand warmers
1 ziploc bag containing:
   1 4 oz bottle with 1 HotHands hand warmer (to be cut open)
   1 pair of scissors to cut open HotHands hand warmer
   1 4 oz bottle containing contents of hand warmer exposed to air for 24 hours

B. Anhydrous Calcium Chloride mixed with water
16 new test tubes in test tube rack, 16 thermometers (from above)
8 4 oz jars of anhydrous calcium chloride (shared by pairs), 16 spoons (from above), 8 water bottles

Divide students into pairs.

I. Introduction

Learning Goals:
• Students understand what endothermic and exothermic reactions are, and they understand that endothermic feel cold and exothermic feel hot.

Share the following explanation of endothermic and exothermic processes with students:
• Tell students that the word “exothermic” describes processes that give off heat.
  “Ex” indicates “out of” or “giving off”, for example, exit, exhale (to breathe out), and exodus.
  “Thermic” indicates heat.
• “Endothermic”, the opposite, is used for processes that absorb heat.
  “En” means “in”, such as “entrance,

In all reactions, energy must be supplied to break bonds and energy is released when bonds are formed.
Tell students to look at the energy level diagrams:

In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds.

Exothermic reactions usually feel hot.
The example shown is for rusting of iron to iron oxide (rust). Students will do this experiment with the HotHands warmer.

Your Notes:
In an endothermic reaction the energy needed to break existing bonds is greater than the energy released from forming new bonds.

Endothermic reactions usually feel cold.
The example shown is for dissolving ammonium nitrate in water. Students will do this experiment as well as be shown a cold pack that uses ammonium nitrate.

II. Endothermic Processes

Learning Goals:
Students perform a variety of endothermic reactions and are able to identify them by feel and looking at a thermometer.
- Students can explain what is happening with the bonds of the molecules in endothermic reaction.

Materials: GOGGLES for ALL
1 cold pack
16 test tube racks, containing 3 test tubes
16 thermometers
8 4 oz jars of ammonium nitrate
16 white spoons
8 water bottles (shared by pairs)
1 paper towel
32 observation sheets
16 instruction sheets in sheet protectors

Examples are:

a. Melting ice to water.
   Some curious students may find it difficult to understand why ice melting is an endothermic reaction, because it seems that absorbing energy should make things hotter. But when you hold a piece of ice on your hand, the ice melts because it is absorbing heat from your hand. As a result, your hand gets colder.

b. Boiling water to water vapor. Sweating is related to this, and is an important endothermic process. It helps maintain our body temperature at normal by cooling us because the evaporation of water from our skin absorbs excess heat from our skin.

c. Photosynthesis is an excellent example of an endothermic chemical reaction where light energy is supplied by the sun.

A. Endothermic Experiment #1– Dissolving Ammonium Nitrate in Water
Ask students if they know what a cold pack is. When is it used?

It is a product that is used to treat muscle sprains or minor injuries.
- Show the students a cold pack. Activate it (by squeezing it firmly) and pass it around the room for the students to feel. (Make sure it is returned to the VSVS lab.)
- Share the following information with the students:

Your Notes:
Some cold packs use the chemical ammonium nitrate. There is a plastic bag of water and a plastic bag of ammonium nitrate inside the cold pack. The cold pack is activated by breaking the plastic divider (done by squeezing the pack) between the water and ammonium nitrate, causing them to mix. When ammonium nitrate dissolves in water, heat is absorbed and the packet feels cold.

In this next activity the temperature change will be measured for the process of dissolving ammonium nitrate in water.

**Safety Note:** Ammonium nitrate solution is a skin irritant and causes a burning sensation. It is toxic by ingestion and inhalation and is a skin, eye and respiratory irritant.

- In this experiment, ammonium nitrate is dissolved in water, and thermal energy from the water is absorbed. The temperature change will be measured to show that thermal energy is used.
- **Background:** When dissolving a solid in a liquid, energy is first required to break the bonds of the crystal. Then, energy is released again when the water forms bonds with the dissolved particles. Some chemicals, like ammonium nitrate, have chemical properties such they require more energy to break their bonds than is released when the new bonds are formed. This energy “debt” is drawn from the thermal energy of the water, reducing the temperature. **It’s all about balance!!**
- Ask students how they will be able to tell if thermal energy is being used. **The temperature will decrease.**

Give each pair the following:
1. test tube rack containing 3 test tubes
1. plate
1. stirrer
1. thermometer
1. water bottle
2. taster spoons
2. observation sheets
1. instruction sheet in a protector
2. pair goggles

Distribute the 8 ammonium nitrate jars, ammonium nitrate molecules and 16 spoons so that two pairs of students can share them.

Tell each pair to:
1. Fill the test tubes HALFWAY.
2. Place the thermometer in the water.
3. Record the temperature of the water on the observation sheet. Use the Celsius scale.
4. Remove the thermometer.
5. Add 2 taster spoons of ammonium nitrate to the test tube.
6. Stir with a plastic stirrer until the solid is mostly dissolved (there can be a little solid left in the bottom).

**Your Notes:**

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
7. Put the thermometer back into the test tube (ALL THE WAY TO THE BOTTOM) and record the lowest temperature reached.

Ask students what temperature difference they observed. Write some values on the board. (Students should observe a decrease of close to 10 degrees). Ask students: Is this an exothermic or endothermic process? Endothermic because the temperature decreased.

Explaining Dissolving at a Molecular Level
Ask students: What is happening when you dissolve ammonium nitrate? Dissolving the ammonium nitrate separates it into ions.

Tell students to refer to the energy diagram on their Handout.

Have students look at the diagram of ammonium nitrate $\text{NH}_4\text{NO}_3$ solid dissolving in water. Explain that energy is needed to break the bonds in the $\text{NH}_4\text{NO}_3$ solid salt molecule to form ammonium ($\text{NH}_4^+$) and nitrate ($\text{NO}_3^-$) ions.

- Ammonium nitrate has an energy debt – it requires more energy to break bonds. It resolves this debt by pulling energy from the thermal energy of the water. It’s all about balance!!

This causes the temperature of the water to decrease.

Hand out the ammonium nitrate models to groups of 4 students

When the ammonium nitrate dissolves in water, it breaks into two separate ions.

$$\text{NH}_4\text{NO}_3 (s) \rightarrow \text{NH}_4^+ (aq) + \text{NO}_3^- (aq)$$

Energy is needed to break bonds.

Explain that we needed energy to do this.

Disposal: Pour the solutions from the test tubes into the sink or the waste bottle provided, or tell students to securely screw the lids onto the test tubes and return to the VSVS lab. MAKE SURE THAT NO LIQUIDS CAN LEAK – PLEASE.

Endothermic Experiment #2 – Reacting Sodium Bicarbonate with Citric Acid

Materials
16 clean test tubes in test tube rack
16 thermometers (from above)
16 white taster spoons

Your Notes:
16 2oz bottles citric acid solution
8 jars sodium bicarbonate
Tell each pair to:
1. Wipe the thermometer dry with a paper towel.
2. Pour the citric acid from the bottle into the test tube.
3. Place the thermometer in the liquid – make sure it is resting on the bottom of the test tube
4. Record the temperature on the observation sheet.
5. Add 1 white taster spoon of sodium bicarbonate to the test tube.
6. Record the temperature reading reached. This will take a few minutes. (Students should observe a decrease of about 4 degrees C)

Ask students: Is this an exothermic or endothermic process? *Endothermic because the temperature decreased.*

In the presence of water, citric acid \([C_6H_8O_7]\) and sodium bicarbonate \([NaHCO_3]\) (aka baking soda) react to form sodium citrate \([Na_3C_6H_5O_7]\), water, and carbon dioxide \([CO_2]\).

\[ C_6H_8O_7 + 3NaHCO_3 \rightarrow Na_3C_6H_5O_7 + 3H_2O + 3CO_2 \]

III. Exothermic Reactions

**Learning Goals:**
- Students perform a variety of exothermic reactions and are able to identify them by feel and looking at a thermometer.
- Students can explain what is happening with the bonds of the molecules in an exothermic reaction.

**Materials**
16 new test tubes in test tube rack
16 thermometers (from above)
8 4 oz jars of anhydrous calcium chloride (shared by pairs)
16 white taster spoons (from above)
16 water bottles
8 HotHands hand warmers
1 ziploc bag containing:
  1 4 oz bottle with 1 HotHands hand warmer (to be cut open)
  1 pair of scissors to cut open HotHands hand warmer
  1 4 oz bottle containing contents of hand warmer exposed to air for 24 hours

Tell students to refer to the Energy diagram on their handout.

**Your Notes:**
Remind them that FORMING a chemical bond releases energy and is therefore exothermic. Burning natural gas (like propane) to heat homes is an example of an exothermic chemical change.

Fun fact: Liquid water freezing to ice releases heat – it is exothermic. An example of an application of this is the practice of spraying water on fruit trees in northern Florida when a light freeze is expected. The water freezes on the fruit, and in the process, releases enough heat to keep the fruit from freezing.

Exothermic Experiments:
A. Chemical (HotHands) Hand Warmer
   • Distribute the 8 HotHands hand warmers to every other pair and tell students to share among two pairs.
   • Have one of the students tear open the plastic covering, have the group members feel the hand warmer and note that it is at room temperature.
   • A group member should shake it, and put it aside.

Note: The directions on the plastic covering suggest waiting 30 minutes, but students will be able to feel warmth from the hand warmer after about ten minutes. Have students go on to Part B while they are waiting for the handwarmers to get warm.

B. Calcium Chloride mixed with water
Distribute 8 4-oz calcium chloride jars so they can be shared by two pairs. Students should still have the white taster spoons to use.

Tell each pair to:
1. Fill the test tubes HALFWAY with water.
2. Place the thermometer in the water.
3. Record the temperature of the water on the observation sheet.
4. Remove the thermometer.
5. Add 2 taster spoons of anhydrous calcium chloride to the test tube.
6. Stir carefully with the plastic stirrer.
7. Put the thermometer back into the test tube (making sure it rests on the bottom of the test tube) and record the highest temperature reached.

Students should observe an increase of 10-20°C.

Ask students: Is this an exothermic or endothermic process? Exothermic because heat is given off. Earlier we said that it takes energy to dissolve molecules, so why does water heat up when we add CaCl₂ to it? The calcium molecule is special, because it forms a strong bond with the water. This means that more energy is released when the calcium chloride bonds with water than was needed to break the crystal bonds. It’s all about balance!!

We are going to demonstrate this phenomenon using our molecular models. Take the molecule out of the bag labelled calcium chloride.
   Break apart the calcium chloride molecule. Energy is needed to break the molecule apart to dissolving it.

Your Notes:
Now make the molecule with a calcium ion and 2 water molecules. Forming bonds creates energy. There is more energy created than used, and this causes the temperature of the water to increase.

Tell students that calcium chloride is used to salt roads in the winter. Calcium chloride is used instead of sodium chloride for three reasons:

1. calcium chloride gives off heat when it mixes with water
2 & 3. calcium chloride combines with water to become hydrated calcium chloride - this removes the water so that there is less available to re-freeze

C. Checking the HotHands Hand Warmer

- Have the students feel the hand warmer. (It should feel warm.)
- Have students look at their observation sheet to read the list of ingredients in the HotHands warmer.
- Tell the class that the “missing ingredient” that is needed to make the hand warmer warm up is oxygen. When the plastic covering is removed, the inside pouch is porous enough to allow air to enter the pouch. The oxygen in air reacts with iron to form iron oxide with the release of heat. This is the common reaction called RUSTING.
- Ask students if this is an example of an endothermic or exothermic process? *Exothermic, heat is released*
- Take the empty 4 oz jar, cut open a hand warmer pouch and pour the contents inside the jar. Show the students this jar and compare what the contents look like with the jar that contains contents of a HotHands hand warmer that were exposed to air for 24 hours.
- *(In the 24-hour jar, the black color of iron powder has changed to a brownish, somewhat clumpy solid, which is iron oxide. The change in color and characteristics of the solid are evidence for a chemical change.)*

**Background Information:** The HotHands hand warmer is an exothermic chemical reaction that occurs when powdered iron is mixed with activated carbon, water, salt, and vermiculite in the presence of air. This involves the quick formation of iron oxide (activated carbon catalyzes the reaction). The same reaction (iron + oxygen + water in the presence of salt) is the corrosion (rusting) process, but it happens much more slowly.

The HotHands handwarmer can be left in the classroom with the teacher or the students, returned to the VSVS lab or kept by the VSVS members.

**IV. Review:**

**Your Notes:**

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________
• Be sure to go over the answers carefully. Students will not likely have correct responses for the last row so it is important that you discuss these and ask them to write the correct answers on their observation sheet. See answer sheet on next page.

Lesson written by: Dr. Melvin Joesten, Professor Emeritus, Vanderbilt University
Pat Tellinghuisen, Program Coordinator of VSVS, Vanderbilt Universit

ENDOTHERMIC/EXOTHERMIC OBSERVATION SHEET

NAMES _______________________________________________________________________

Vocabulary words:
endothermic ammonium nitrate sodium bicarbonate citric acid
exothermic calcium chloride Hot Hands

Ingredients in chemical hand warmer (Hot Hands): Iron, activated carbon, water, salt, and vermiculite.

<table>
<thead>
<tr>
<th>Ammonium Nitrate added to water</th>
<th>Sodium Bicarbonate added to Citric Acid</th>
<th>Calcium Chloride added to water</th>
<th>Hot Hands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of liquid</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Temperature of liquid + chemical</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Temperature change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did it get hotter or colder?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is it Endothermic or Exothermic?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Why?</td>
<td>Bonds are being formed. Bonds are being broken.</td>
<td>Bonds are being formed. Bonds are being broken.</td>
<td>Bonds are being formed. Bonds are being broken.</td>
</tr>
</tbody>
</table>

Your Notes:
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
## Endothermic/Exothermic Observation Sheet

### Names

Vocabulary words:
- endothermic
- ammonium nitrate
- sodium bicarbonate
- citric acid
- exothermic
- calcium chloride
- Hot Hands

Ingredients in chemical hand warmer (Hot Hands): Iron, activated carbon, water, salt, and vermiculite.

<table>
<thead>
<tr>
<th></th>
<th>Ammonium Nitrate added to water</th>
<th>Sodium Bicarbonate added to Citric Acid</th>
<th>Calcium Chloride added to water</th>
<th>Hot Hands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of liquid</td>
<td>22 °C</td>
<td>22 °C</td>
<td>22 °C</td>
<td>X</td>
</tr>
<tr>
<td>Temperature of liquid + chemical</td>
<td>11 °C</td>
<td>18 °C</td>
<td>37 °C or more</td>
<td>X</td>
</tr>
<tr>
<td>Temperature change</td>
<td>About -11 °C</td>
<td>About -4 °C</td>
<td>About +15 °C or more</td>
<td>Got warmer</td>
</tr>
<tr>
<td>Did it get hotter or colder?</td>
<td>Colder</td>
<td>Colder</td>
<td>Hotter</td>
<td>Hotter</td>
</tr>
<tr>
<td>Is it Endothermic or Exothermic?</td>
<td>Endothermic</td>
<td>Endothermic</td>
<td>Exothermic</td>
<td>Exothermic</td>
</tr>
<tr>
<td>Why?</td>
<td>Bonds are being formed.</td>
<td>Bonds are being formed.</td>
<td>Bonds are being formed.</td>
<td>Bonds are being formed.</td>
</tr>
</tbody>
</table>
MORE Energy is…

<table>
<thead>
<tr>
<th></th>
<th>Used</th>
<th>Used</th>
<th>Used</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Released</td>
<td>Released</td>
<td>Released</td>
<td>Released</td>
</tr>
</tbody>
</table>
Evidence of a Chemical Reaction

Goal: To show students evidence of a chemical change.

Fits TN standards:
GLE 0807.9.8: Interpret the events represented by a chemical equation
GLE 0807.9.3: Interpret data from an investigation to differentiate between physical and chemical changes
GLE 0807.9.4: Distinguish among elements, compounds, and mixtures
GLE 0507.9.1: Observe and measure the simple chemical properties of common substances

VSVSer Lesson Outline

I. Introduction
Question students about the difference between physical and chemical changes. 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)
Students should realize that if the solution turns cloudy, a solid (precipitate) is forming.

Row B: Chemical Reactions That Involve a Color Change
Formation of complex ions cause color changes.

Row C: Chemical Reactions That Produce a Gas
Students look carefully at the bubbles (CO₂) produced in solutions.

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

V. Review

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM (https://studentorgs.vanderbilt.edu/vsvs/lessons/)
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. In the car ride, 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) What are some basic differences between a physical and chemical change?
2) What are signs of a chemical change?
3) What are the major safety concerns in this lesson for students?
4) What is important about the reaction between a carbonate/bicarbonate and an acid?
5) What is a precipitate?
6) Briefly describe the process students will use to “identify the unknown” at the end of the lesson.
7) If a reaction causes the solution to go from colored to clear, does it count as a color change?
8) In all of the reactions in this lesson for which a gas is given off, what is the gas?

2. Use these fun facts during the lesson:
   - Chemical changes constantly occur in living organisms. The human body is made up of proteins that help catalyze complex chemical reactions.
   - The products of a chemical reaction have the same total mass as the reactants (law of conservation of mass).

Unpacking the Kit – What you will need for each section:
   - VSVSers do this while 1 person is giving the Introduction. Note that students are put into pairs and should have their pencils ready.
   - 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

For Part III. Determining If a Chemical Change Has Occurred

15 sets of dropper bottles of each:
- 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

A. Demonstration Bag A – 2 oz bottle of 0.1 M CaCl₂, 2 oz bottle of 1 M Na₂CO₃, 2 10 oz clear cups 4 jars containing the products, with precipitate in bottom
B. Demonstration Bag B – 2 oz bottle of 0.05 M Na₂S₂O₃, 2 oz bottle of 0.01 M I₂, 2 10 oz clear cups
C. Demonstration Bag C - 2 oz bottle of 1 M HCl, jar of Na₂CO₃, 1 teaspoon, and 1 10 oz clear cup

For Part IV. Analyzing Results

15 small pieces of marble CaCO₃ (in a small bag)

For Part V. Optional: Identifying an Unknown

2 sets of 1oz dropper bottles of each of the following unknowns: Unknown A: NaHCO₃, Unknown B: CaCl₂, Unknown C: HCl, Unknown D: KSCN,
I. Introduction

Learning Goals: Students can name the different indicators that a chemical reaction has occurred.

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 answers may 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.

1. 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.

2. 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.

3. A precipitate forms when two substances react to give a new solid compound that does not dissolve in water.
   - A precipitate will MOST LIKELY look like a cloudy solution, fine grains in a solution, a swirl, or a fluffy solid. The solution cannot be seen through.

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.

4. An energy change (temperature or light) can be either a physical or chemical change. A chemical

Your Notes:
energy change occurs in a glow stick when chemicals mix to produce light. A physical energy change occurs when you freeze water.

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.

II. Safety Concerns
- Tell students they must put on safety goggles before mixing any solutions.
- Students should not directly smell any chemicals.
- 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
- 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 names and formulas of the compounds being used in this experiment are listed at the bottom of the observation sheet. Have students look at these names and formulas while you pronounce them for the class. 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).

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.

Your Notes:
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

**Learning Goals:**
- Students can name the different indicators that a chemical reaction has occurred.
- Students can identify the specific indicators of a reaction and explain how to look for them

---

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

**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.

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.
Show the students the jars with the clear liquid and precipitate in the bottom. Tell them that these are the products from the same reaction just done, but the products were allowed to stand for several hours. Shake the jar to show the students that the solution will become cloudy again.

Tell students to use the grid on their observation sheet to perform the experiments in Row A. Make sure that they correctly identify the formulas of the compounds being used in a reaction (listed on the observation sheet).

**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**
- Students can look at the equations on the observation sheet:
  - Demo: CaCl$_2$ + Na$_2$CO$_3$ → CaCO$_3$ + 2 NaCl
  - A1: 2 Fe(NO$_3$)$_3$ + 3 Na$_2$CO$_3$ → Fe$_2$(CO$_3$)$_3$ + 6 NaNO$_3$
  - A2: Cu(NO$_3$)$_2$ + Na$_2$CO$_3$ → CuCO$_3$ + 2 NaNO$_3$

**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 oz 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$_6^{2-}$.

---

Your Notes:

______________________________________________________________________________
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.**
  Students can look at the equations on their observation sheet.
  
  **Demo:** $I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$
  
  **B1:** $Fe(NO_3)_3 + KSCN \rightarrow Fe(SCN)(NO_3)_2 + KNO_3$
  intense red color
  
  **B2:** $Cu(NO_3)_2 + KSCN \rightarrow Cu(SCN)(NO_3) + KNO_3$
  pale green color

**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 $Fe^{3+}$ (iron) ion in solution to give an intense deep red color. The SCN⁻ anion also bonds to Cu(II) (copper) ion.

---

**C. Chemical Reactions that Produce a Gas - Row C**

**Note:** Tell students they will have to look very closely and quickly as soon as they add the second solution to the first solution. The bubbles of gas are small and come off as soon as the solutions are mixed.

**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 tsp of the solid (Na₂CO₃) into the cup and empty the 2oz 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**
- Students can look at the equations on the observation sheet.
  
  **Demo:** $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$
  
  **C1:** $NaHCO_3 + HCl \rightarrow NaCl + CO_2 (g) + H_2O$
  
  **C2:** $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 (g) + H_2O$

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
IV. Analyzing Results

Learning Goals: Students can analyze compounds’ reactions with one another and use that data to identify an unknown compound.

Carbonates:
- Write CO$_3$ on the board and tell students that formulas that include “CO$_3$” as part of the formula are called carbonates.
- 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 on their Instruction sheet. 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.
- 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.
- 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 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, CaCO$_3$ (s) + HCl (aq) → ...on the board, and ask students to hypothesize what will happen, and what the products will be. The gas will be CO$_2$.
  The full equation is:

Your Notes:
CaCO$_3$ + 2HCl $\rightarrow$ CaCl$_2$ + CO$_2$ + H$_2$O

- 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 in rain drops. 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.

V. **Optional: Identifying an Unknown**

Tell students they will be given a colorless solution that contains one of the following compounds dissolved in water:

- Unknown A: NaHCO$_3$
- Unknown B: CaCl$_2$
- Unknown C: HCl
- Unknown D: KSCN

These are the same colorless solutions that they have been doing the experiments with, except that CaCl$_2$ was used only in Demonstration A.

Tell them that they will follow a plan, using the dropper bottles from the chemical reaction kit, to determine the identity of the unknown.

Students can work in pairs, groups, or as a class.

Distribute the 8 unknown dropper bottles throughout the class, so that pairs or groups of students have access to one unknown.

Tell students to:

1. Follow the plan in Row D and add a squirt of their unknown to the 6 wells in Row D of the well plate.
2. Add a few drops from their known dropper bottles, one well at a time.
3. Write down the observation immediately after each addition.
4. Look at the results in Rows A, B and C, including the demonstration reactions, to determine what the possible reactions are.

Ask students: What do you think your unknown is? _____________

What is your proof for what you’ve listed in (a)?

Your Notes:
The proof should be stated something like the answer response in the plans given above but specific for the unknown. For example, if the unknown was CaCl$_2$, the proof statement could be: A precipitate formed when Na$_2$CO$_3$ solution was added. The CaCl$_2$ solution is the only one of the possible unknowns that will give a precipitate with Na$_2$CO$_3$.

Write balanced chemical equations for the reactions you used to determine the identity of the unknown. (Refer to equations in lesson (Section VIII))

Optional: Answer these questions after finishing the chemical reactions observation sheet.

1. Write complete, balanced equations for the following:
   a. One reaction in Row A that gave a precipitate.  
      Refer to equations in lesson (Section VIII)
   b. One reaction in Row B that gave a color change. 
      Refer to equations in lesson (Section VIII)
   c. One reaction in Row C that gave a gas. 
      Refer to equations in lesson (Section VIII)

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 Ziploc bag. Make sure 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 instruction sheets in sheet protectors and put them in the box.

Lesson written by Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Class Activity Sheet – Extension Activity

NAME ____________________________________________

1. You will be given an unknown colorless solution that contains one of the following compounds dissolved in water: CaCl₂, KSCN, HCl, NaHCO₃. Follow Row D to determine the identity of your unknown.
   a. What do you think your unknown is? _____________ If there is more than one possibility, list both.
   
   b. What is your proof for what you’ve listed in (a)?
   
   c. Write balanced chemical equations for the reactions you used to determine the identity of the unknown.

1. Write complete, balanced equations for the following (choose a correct equation from the list below):
   a. One reaction in Row A that gave a precipitate.
   
   b. One reaction in Row B that gave a color change.
   
   c. One reaction in Row C that gave a gas.

**Chemical Equations for Chemical Reactions in this Lesson**

Abbreviations: s = solid, aq = aqueous, g = gas, l = liquid

- CaCl₂ (aq) + Na₂CO₃ (aq) → CaCO₃ (s) + 2 NaCl (aq)
- 2 Fe(NO₃)₃ (aq) + 3 Na₂CO₃ (aq) → Fe₂(CO₃)₃ (s) + 6 NaNO₃ (aq)
- Cu(NO₃)₂ (aq) + Na₂CO₃ (aq) → CuCO₃ (s) + 2 NaNO₃ (aq)
- I₂(aq) + 2 NaS2O₃(aq) → 2 NaI(aq) + Na₂S₄O₆ (aq)
- Fe(NO₃)₃ (aq) + KSCN (aq) → Fe(SCN)(NO₃)₂ (aq) + KNO₃ (aq)
- Cu(NO₃)₂ (aq) + KSCN (aq) → Cu(SCN)(NO₃)₂ (aq) + KNO₃ (aq)
- Na₂CO₃ (s) + 2HCl (aq) → 2NaCl (aq) + CO₂ (g) + H₂O (l)
- NaHCO₃ (aq) + HCl (aq) → NaCl (aq) + CO₂ (g) + H₂O (l)
- Na₂CO₃ (aq) + 2HCl (aq) → 2NaCl (aq) + CO₂ (g) + H₂O (l)
- CaCO₃ (s) + 2HCl (aq) → CaCl₂ (aq) + CO₂ (g) + H₂O (l)

Your Notes:
__________________________________________________________________________________________
__________________________________________________________________________________________
2. Write complete, balanced equations for the following:
   a. One reaction in Row A that gave a precipitate.
      **Refer to equations on worksheet**
   b. One reaction in Row B that gave a color change.
      **Refer to equations on worksheet**
   c. One reaction in Row C that gave a gas.
      **Refer to equations in lesson (Section VIII)**

2. You will be given an unknown colorless solution that contains one of the following compounds dissolved in water: CaCl₂, KSCN, HCl, NaHCO₃. Follow Row D to determine the identity of your unknown.

   What do you think your unknown is? _____________

5. What is your proof for what you’ve listed in (a)?
   **The proof should be stated something like the answer response in the plans given above, but specific for the unknown. For example, if the unknown was CaCl₂, the proof statement could be:** A precipitate formed when NaHCO₃ solution was added. The CaCl₂ solution is the only one of the possible unknowns that will give a precipitate with NaHCO₃.

6. Write balanced chemical equations for the reactions you used to determine the identity of the unknown.
   **Refer to equations below**
<table>
<thead>
<tr>
<th>A1</th>
<th>Fe(NO₃)₃ + Na₂CO₃</th>
<th>A2</th>
<th>Cu(NO₃)₂ + Na₂CO₃</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6 Demonstration</th>
<th>CaCl₂ + Na₂CO₃ → CaCO₃ + 2NaCl</th>
<th>2 Fe(NO₃)₃ + 3 Na₂CO₃ → Fe₂(CO₃)₃ + 6 NaNO₃</th>
<th>Cu(NO₃)₂ + Na₂CO₃ → CuCO₃ + 2 NaNO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Fe(NO₃)₃ + KSCN</td>
<td>B2</td>
<td>Cu(NO₃)₂ + KSCN</td>
<td>B3</td>
<td>B4</td>
<td>B5</td>
<td>B6 Demonstration</td>
<td>I₂ + 2 Na₂S₂O₃ → 2 NaI + Na₂S₄O₆</td>
<td>Fe(NO₃)₃ + KSCN → Fe(SCN)(NO₃)₂ + KNO₃</td>
<td>Cu(NO₃)₂ + KSCN (aq) → Cu(SCN)(NO₃)₂ + KNO₃</td>
</tr>
<tr>
<td>C1</td>
<td>NaHCO₃ + HCl</td>
<td>C2</td>
<td>Na₂CO₃ + HCl</td>
<td>C3</td>
<td>C4</td>
<td>C5</td>
<td>C6 Demonstration</td>
<td>Na₂CO₃ + 2HCl → 2NaCl + CO₂ + H₂O</td>
<td>NaHCO₃ + HCl → NaCl + CO₂ + H₂O</td>
<td>Na₂CO₃ + 2HCl → 2NaCl + CO₂ + H₂O</td>
</tr>
<tr>
<td>D1</td>
<td>NaHCO₃ + unknown</td>
<td>D2</td>
<td>KSCN + unknown</td>
<td>D3</td>
<td>D4</td>
<td>D5</td>
<td>D6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vocabulary Words: physical change, chemical change, chemical reaction, formula, solution, precipitate, compound, mixture

In each box, use the following choices to record your observations: color change, precipitate formed, gas given off, NR (no reaction)

Add other observations if you wish. Ex: lots of bubbles, fizz, small or large bubbles, cloudy precipitate.
<table>
<thead>
<tr>
<th>A1</th>
<th>Fe(NO₃)₃ + Na₂CO₃</th>
<th>precipitate</th>
<th>A2</th>
<th>Cu(NO₃)₂ + Na₂CO₃</th>
<th>precipitate</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCl₂ + Na₂CO₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>white precipitate</td>
</tr>
<tr>
<td>B1</td>
<td>Fe(NO₃)₃ + KSCN</td>
<td></td>
<td>B2</td>
<td>Cu(NO₃)₂ + KSCN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td>color change -</td>
<td></td>
<td></td>
<td>color change -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I₂ + 2 Na₂S₂O₃</td>
</tr>
<tr>
<td></td>
<td>deep red</td>
<td></td>
<td></td>
<td>pale green color</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>color change –</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>brown to colorless</td>
</tr>
<tr>
<td>C1</td>
<td>baking soda</td>
<td></td>
<td>C2</td>
<td>washing soda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td>NaHCO₃ + HCl</td>
<td></td>
<td></td>
<td>Na₂CO₃ + HCl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Na₂CO₃ + 2HCl</td>
</tr>
<tr>
<td></td>
<td>gas given off</td>
<td></td>
<td></td>
<td>gas given off</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>gas given off</td>
</tr>
<tr>
<td>D1</td>
<td>baking soda</td>
<td></td>
<td>D2</td>
<td>potassium thiocyanate</td>
<td>KSCN</td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td>NaHCO₃ + unknown</td>
<td></td>
<td></td>
<td>KSCN + unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KSCN – potassium thiocyanate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D3</td>
<td>iron nitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fe(NO₃)₃ + unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fe(NO₃)₃ – iron (III) nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D4</td>
<td>copper nitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cu(NO₃)₂ + unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cu(NO₃)₂ – copper (II) nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D5</td>
<td>hydrochloric acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Demonstration</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HCl + unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HCl – hydrochloric acid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes
- **HCl** – hydrochloric acid
- **Na₂CO₃** – sodium carbonate
- **NaHCO₃** – sodium bicarbonate
- **Cu(NO₃)₂** – copper (II) nitrate
- **Fe(NO₃)₃** – iron (III) nitrate
- **KSCN** – potassium thiocyanate
- **CaCl₂** – calcium chloride
<table>
<thead>
<tr>
<th>Unknown A (Na₂CO₃)</th>
<th>Unknown B (CaCl₂)</th>
<th>Unknown C (HCl)</th>
<th>Unknown D (KSCN)</th>
<th>Unknown E (NaHCO₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Answer Sheet for Unknown Solutions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>baking soda</strong></td>
<td><strong>potassium thiocyanate</strong></td>
<td><strong>iron nitrate</strong></td>
<td><strong>copper nitrate</strong></td>
<td><strong>hydrochloric acid</strong></td>
</tr>
<tr>
<td>NaHCO₃ + unknown A (Na₂CO₃)</td>
<td>KSCN+ unknown A (Na₂CO₃)</td>
<td>Fe(NO₃)₃+ unknown A (Na₂CO₃)</td>
<td>Cu(NO₃)₂+ unknown A (Na₂CO₃)</td>
<td>HCl + unknown A (Na₂CO₃)</td>
</tr>
<tr>
<td>NR</td>
<td>NR</td>
<td>PPT</td>
<td>PPT</td>
<td>Gas given off</td>
</tr>
<tr>
<td><strong>baking soda</strong></td>
<td><strong>potassium thiocyanate</strong></td>
<td><strong>iron nitrate</strong></td>
<td><strong>copper nitrate</strong></td>
<td><strong>hydrochloric acid</strong></td>
</tr>
<tr>
<td>NaHCO₃ + unknown B (CaCl₂)</td>
<td>KSCN+ unknown B (CaCl₂)</td>
<td>Fe(NO₃)₃+ unknown B (CaCl₂)</td>
<td>Cu(NO₃)₂+ unknown B (CaCl₂)</td>
<td>HCl + unknown B (CaCl₂)</td>
</tr>
<tr>
<td>PPT</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>baking soda</strong></td>
<td><strong>potassium thiocyanate</strong></td>
<td><strong>iron nitrate</strong></td>
<td><strong>copper nitrate</strong></td>
<td><strong>hydrochloric acid</strong></td>
</tr>
<tr>
<td>NaHCO₃ + unknown C (HCl)</td>
<td>KSCN+ unknown C (HCl)</td>
<td>Fe(NO₃)₃+ unknown C (HCl)</td>
<td>Cu(NO₃)₂+ unknown C (HCl)</td>
<td>HCl + unknown C (HCl)</td>
</tr>
<tr>
<td>Gas given off</td>
<td>NR</td>
<td>PPT</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>baking soda</strong></td>
<td><strong>potassium thiocyanate</strong></td>
<td><strong>iron nitrate</strong></td>
<td><strong>copper nitrate</strong></td>
<td><strong>hydrochloric acid</strong></td>
</tr>
<tr>
<td>NaHCO₃ + unknown D (KSCN)</td>
<td>KSCN+ unknown D (KSCN)</td>
<td>Fe(NO₃)₃+ unknown D (KSCN)</td>
<td>Cu(NO₃)₂+ unknown D (KSCN)</td>
<td>HCl + unknown D (KSCN)</td>
</tr>
<tr>
<td>NR</td>
<td>NR</td>
<td>PPT</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>baking soda</strong></td>
<td><strong>potassium thiocyanate</strong></td>
<td><strong>iron nitrate</strong></td>
<td><strong>copper nitrate</strong></td>
<td><strong>hydrochloric acid</strong></td>
</tr>
<tr>
<td>NaHCO₃ + unknown E (NaHCO₃)</td>
<td>KSCN+ unknown E (NaHCO₃)</td>
<td>Fe(NO₃)₃+ unknown E (NaHCO₃)</td>
<td>Cu(NO₃)₂+ unknown E (NaHCO₃)</td>
<td>HCl + unknown E (NaHCO₃)</td>
</tr>
<tr>
<td>NR</td>
<td>NR</td>
<td>PPT</td>
<td>PPT</td>
<td>Gas given off</td>
</tr>
</tbody>
</table>
Goal: To understand factors which affect the rates of chemical reactions - temperature, concentration of reacting substances in solutions, surface area (particle size) of solids in reactions with gases and liquids, and catalysts.

TN Curriculum Alignment:
GLE 0807.9.3: Interpret data from an investigation to differentiate between chemical and physical changes.
PS CLE 3202.1.4 Investigate chemical and physical changes.

VSVS Lesson Outline

I. Background
Gives overview of experiment.

II. Effect of Temperature
Students observe how fast bubbles of carbon dioxide are produced when room-temperature water and ice water are added to effervescent tablets in dry cups.

III. Effect of Concentration
Students observe the difference in how fast bubbles of carbon dioxide are produced when two different concentrations of vinegar are added to baking soda.

IV. Effect of Surface Area – Demonstration.
Dust in a flame - Spray lycopodium powder into the flame of the tea candle. This produces a large flame because of the rapid burning of the lycopodium powder due to its small particle size and therefore its large surface area that is exposed to the oxygen in the air.

V. Effect of Surface Area – Experiment with Tablets.
Students observe how fast bubbles of carbon dioxide are produced when water is added to a whole tablet and a crushed tablet in dry cups.

VI. Effect of Surface Area – Demonstration.
Dust Can Explosion
Spray lycopodium powder into a can with a lit tea candle. This causes the same rapid burning of the lycopodium powder demonstrated in Part IV. The large volume of combustion gases (carbon dioxide and water vapor) causes the lid of the can to blow off.

VII. Effect of Catalysts
VSVS members demonstrate the use of manganese dioxide, MnO₂, as a catalyst for the rate of decomposition of hydrogen peroxide to water and oxygen by adding a small plastic scoop of MnO₂ to a clear jar containing hydrogen peroxide.

VIII. Review

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. Before the lesson:
In the car ride, 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.
1. Describe how the following factors influence the rate of a chemical reaction: temperature, concentration, surface area, and catalysts.
2. What are some visual indications that a chemical reaction has occurred?
3. A catalyst is consumed in a reaction – True/False?

2. Use these fun facts during the lesson:
   - The reaction rate can be changed by adding energy such as heat, sunlight, or electricity.
   - An example of how temperature affects reaction rates is that cookies bake faster at higher temperatures.
   - Reaction rates are based upon the speed at which reactant particles are colliding with each other.
   - Some reactions take thousands of years while others can happen in less than a second. The decomposition of dead animals into oil is a prime example of the former and the reaction of vinegar and baking soda is instantaneous.
   - When one reaction triggers another, it is called a chain reaction.
   - Without enzymes, many bodily functions would occur at a much slower rate, while others would not occur at all! The stomach and saliva have enzymes that digest food; without them, the food you eat would sit inside of you forever and your body would not receive the nutrients it needs to survive.

Unpacking the Kit – What you will need for each section:
VSVSers do this while 1 person is giving the Introduction.

Note that students are put into groups of 3
Students should have their pencils ready
One VSVS team member should write the following vocabulary words on the board while another member starts discussing the background information:
  rate  concentration  chemical reaction  catalyst  surface area

For Part I. (At end of Introduction)
20  Instruction Sheets (in sheet protectors) (4 for VSVS team)
36  Observation Sheets (one per student)

For Part II. The Effect of Temperature on the Rate of a Reaction
1  container of ice
12  3.5 oz cups marked for 50 mL containing ice
12  3.5 oz cups marked for 50 mL NOT containing ice
24  10 oz. clear plastic cups
12  bottles of water
12  plates
12  packets of 2 effervescent tablets
12  pairs of scissors

For Part III.  Effect of Concentration on the Rate of a Reaction
Materials for demonstration
1 plastic bag containing:
  2  100 mL graduated cylinders (clear)

Your Notes:
1 jar Koolaid powder
1 200 mL bottle of water
1 piece of copy paper
1 mini scoop

Materials for the experiment:
12 Ziploc bags containing:
  2 10 oz. clear plastic cups, 2 containers with 50 mL of 20% vinegar, 5% vinegar solutions, 1 container of baking soda and 1 spoon

For Part IV. The Effect of Surface Area: Demonstration
Materials needed for the Dust in a Flame Demonstration are in the Coffee Can which contains:
1 box of matches 1 vial of lycopodium "dust" powder
1 pipette (jumbo size) 1 tea light candle
1 aluminum pan

For Part V. The Effect of Surface Area on the Rate of a Reaction Experiment
24 10 oz dry cups, 12 packets of 2 effervescent tablets, 12 small Ziploc bags
(Students should already have two 3.5 oz cups that they used in Section II, the bottle of water, a pair of scissors, and a plate.)

For Part VII. Effect of a Catalyst
1 demo bag containing:
  1 clear 6-oz screw-cap jar one-third full of 1.5% hydrogen peroxide, 1 small container of manganese dioxide, 1 small plastic scoop, 2 splints, 1 box of matches, 1 bottle hydrogen peroxide (empty)

I. Introduction

Learning Goals:
- Students understand what is meant by “the rate of a reaction”.
- In Parts II-VII, students will understand the different factors that affect the rate of a reaction and why. In addition, they are able to discuss the opposite side of each factor, ie how to slow the reaction down.

Share the following information with the students:
- A chemical change or chemical reaction occurs when two or more substances react to form new substances with different chemical properties.
- Evidence of a chemical reaction might be a color change, a gas given off, or the formation of a precipitate.

Ask students what they know about Alka Seltzer or effervescent tablets.
Include the following information in the discussion.
- Tell students that effervescent tablets are commonly referred to as Alka Seltzer tablets because these were the first effervescent tablets available.
- Effervescent tablets contain citric acid and sodium bicarbonate. When water is added, these ingredients dissolve and react with each other to produce carbon dioxide gas.

Your Notes:
is a **chemical reaction** as evidenced by the production of a gas.

- The rate of the reaction can be measured by measuring the rate at which carbon dioxide is given off.

Share the following information with the students:

- The **rate** of a chemical reaction is how fast the reaction occurs.
- Many reactions occur so fast that you cannot measure how long it takes. Others take years or longer to occur.
- Factors that affect the rate of reaction include **temperature, concentration, surface area, and catalysts**. Write these factors on the board so that you can reference them over the course of the lesson.
- Tell students that the activities today will demonstrate how these factors influence the rate of a chemical reaction.

### II. The Effect of Temperature on the Rate of a Reaction

#### Introduction

| Learning Goals: Students the effect of temperature on the rate of a reaction. |

Ask students: What happens to food that is left out in the open on a hot day or in a hot room? *melts, spoils, molds, gets hard, ripens, stays the same and other responses – depending on the food item*

Ask students: Since some foods spoil in heat, what do we do to slow down the rate of food spoilage?

Include the following information in the discussion:

- We refrigerate or freeze foods to delay the rate of food spoilage.
- The lower the temperature, the slower the reaction. Conversely, the higher the temperature, the faster the reaction.
- We know that food left out on a hot summer day can spoil fairly quickly. By cooling the food, we slow the chemical reaction of spoilage.
- Since food spoilage is a chemical reaction, this example illustrates the effect of temperature on the rate of a chemical reaction.

**Note:** While one VSVS volunteer starts handing out materials to each group, another VSVS volunteer should fill 12 of the 3.5 oz measuring cups to the 50 mL line with ice. This cup and another empty 3.5 oz measuring cup should be given to each **group of 3**.

#### Procedure:

Give each GROUP the following:

- 1 plate
- 1 bottle of water
- 2 10 oz. cups
- 1 pair of scissors
- 1 packet of 2 effervescent tablets
- 1 3.5 oz cup filled with ice to the 50 mL line
- 1 3.5 oz cup marked with a 50 mL line
- 4 observation sheets

**Your Notes:**

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Have students do the following (these instructions are on their Instruction Sheet):

- Place the two 3.5oz cups (one already contains ice) on a plate.
- Fill both cups to the 50 mL line with water. (The ice cup will not require much water to reach the mark.)
- Carefully cut open one end of the packet of effervescent tablets.
- Carefully remove the effervescent tablets from the packet.
- Add a whole tablet to each of the 10oz clear dry cups.
- Place the two cups with the tablets on the plate.
- VSVS team members should make sure groups are ready by asking two students from each group to hold a 3.5oz cup with water or ice water in a “ready” position over the dry cup containing a tablet. Tell all students to be ready to observe what happens when the tablets are added.
- Then one of the VSVS team says "1,2,3, Go," and on “Go,” the students add all the water or ice from their cups to the tablets in the 10oz cups at the exact same time from the exact same height.
- Observe what happens and write your observations on the observation sheet.

Note: Students should save the 3.5oz measuring cups for Part V. VSVS members should collect the used 10oz cups. Dry ones need to be used in the next section.

Ask students: Was the reaction faster in the ice water or the water at room temperature?

Room temperature water, bubbles of carbon dioxide come off more slowly in ice water.

Discussion:
Ask students: How does this illustrate the effect of temperature on the rate of reaction?

The rate of bubbles coming off in ice water was slower so the lower the temperature the slower the reaction; and the higher the temperature the faster the reaction.

Ask students: How do you think we could make the reaction occur even faster? If they are struggling, suggest a comparison with the effect of temperature of food spoilage mentioned earlier. Do NOT just give them the answer!!

Answer: Heat the water to a higher temperature.

Ask students: Is the total amount of carbon dioxide given off in both the slow and fast reaction the same if you wait until the reaction is over?

Yes. It is important for students to realize that since we started with the same amount of substance, as represented by the whole tablet in both cases, we will get the same amount of carbon dioxide gas when water is added - whether the reaction is fast or slow. The ice water/tablet cup will continue to fizz long after the other one has stopped.

Your Notes:
III. Effect of Concentration on the Rate of a Reaction add iodine clock

Learning Goals: Students understand the concept of concentration and how to tell how concentrated a liquid is.

Materials for demonstration
2 100 mL graduated cylinders (clear)
1 jar grape Koolaid powder
1 200 mL bottle of water
1 piece of copy paper
1 mini scoop

Share the following information with students:
The concentration of a solution refers to how much of a substance is dissolved in water. A stronger (more concentrated) solution has more molecules of the reacting substance in water than a weaker (more dilute) solution does.

Demonstration #1:

Hold up the bottle of Koolaid powder and make sure class can see what you are doing.
- Add 1 scoop to 1 cylinder and 4 scoops to the other.
- Fill both graduated cylinders to 100 mL mark with water.
- Hold graduated cylinders up so students can see the difference in intensity of the color. (Use the piece of white copy paper behind the cylinders to help students see the difference.)
- Ask students which solution would have a stronger taste?
  - The solution made with 4 scoops is stronger. It is four times as strong (i.e., four times more concentrated) as the solution with one scoop.
- Tell students that the weak and stronger vinegar solutions were prepared in a similar way.

DEMONSTRATION #2 – How concentration affects reaction rate

Warn students that the reaction does not occur upon mixing and that they should carefully watch the containers until they observe a color change.

1 Bag Containing:
  2 Containers labeled “Stock Solution”
  1 Container labeled “Dilute Acid Solution”
  1 Container labeled “Concentrated Acid Solution”

Your Notes:

________________________________________________________________________
________________________________________________________________________
- Place the stock solutions next to each other and remove the lids of these containers.
- Remove the lids from the dilute acid solution and the concentrated acid solution. Have two VSVSers hold the acid solutions in “ready positions” above the stock solutions.
- One VSVSer should count down “3, 2, 1, Go.” On “Go,” simultaneously empty the contents of the dilute acid solution and the concentrated acid solution into the stock solutions.
- Immediately after pouring, swirl the stock solutions and tell students to carefully observe what happens.

Ask students to describe what happened. 
*The color changed appeared first in the stock solution where the concentrated acid solution was poured.*

Ask students how this experiment demonstrates the effect of concentration on the rate of a chemical reaction.
*The reaction occurred faster when a higher concentration of acid was used.*

Ask students how the color change could be made to appear even faster.
*By using a greater concentrated acid solution.*

---

**Background for VSVS Members Only:**

Three reactions occur simultaneously:

1. \( \text{H}_2\text{O}_2 + 2\text{I}^- + 2\text{H}^+ \rightarrow \text{I}_2 + 4\text{H}_2\text{O} \) [Slow]
2. \( 2\text{S}_2\text{O}_3^{2-} + \text{I}_2 \rightarrow 2\text{S}_4\text{O}_6^{2-} + 2\text{I}^- \) [Fast]
3. \( \text{I}_2 + \text{I}^- \rightarrow \text{I}_3^- \)

Starch complexes with the triiodide anion, \( \text{I}_3^- \), to give the dark blue solution. However, this anion is formed only when sufficient iodine, \( \text{I}_2 \), and iodide anion, \( \text{I}^- \), are present. Reaction (2) occurs immediately to consume both iodine and, importantly, the thiosulfate anion, \( \text{S}_2\text{O}_3^{2-} \). Reaction (1) reforms the iodine, which can then participate again in Reaction (2). Progressive consumption of the thiosulfate anion occurs through Reaction (2) until the thiosulfate anion is depleted. At this point, sufficient iodine remains in the solution to undergo Reaction (3). However, Reaction (1) is slow and accounts for the time delay of the blue solution.

---

**Experiment:**

Ask students: Have you ever mixed vinegar and baking soda? What happened?
*Most students have done this and will remember that bubbles were formed.*

Tell the students that they will be adding 2 different strengths of vinegar to baking soda.

**Warn students that the reactions in the next experiment will be very fast, and they must observe closely or they will miss the reaction.**

**Give each GROUP OF 3 the following:**

2 10 oz clear plastic cups
1 Ziploc bag containing:
- 2 containers with 50 mL of strong vinegar, weaker vinegar
- 1 container of baking soda, 1 spoon
(They should already have a plate and bottle of water per team)

**Your Notes:**
- Place each of the 2 vinegar solutions beside the cups.
- Place a level spoon of baking soda in each cup.
- VSVS team members should make sure groups are ready by asking two students from each group to remove the top from the vinegar containers and hold it in a “ready” position over a cup of baking soda. The other students should observe closely to see the results.
- Then one of the VSVS team says “1,2,3, Go,” and on “Go,” the students should add all the vinegar solution from their containers to the cups of baking soda at the exact same time from the exact same height.
- Record the results.

Ask students to describe what happened.

_Bubbles of carbon dioxide come off more slowly from the lower concentration (weaker) vinegar._

Ask, How does this illustrate the effect of concentration on the rate of reaction?

_The rate of carbon dioxide bubble formation is slower for the weaker solution of vinegar. The stronger the solution, the more substance there is to react and the faster the reaction will occur._

Ask students: Which reaction was faster? _The strong vinegar should have given a faster reaction._

Ask students: How does this illustrate the effect of concentration on the rate of reaction? _The stronger the solution, the more substance there is to react and the faster the reaction will occur._

**IV. The Effect of Surface Area: Demonstration**

- **Learning Goals:** Students understand surface area as a concept and can distinguish between larger (crushed tablets) and smaller (whole tablets) surface area reagents.

- Ask students: What is surface area? _Students probably will not be familiar with the concept of surface area, so share the following information with them._
- Surface area is the exposed surface of an object.
- Show students a flat piece of paper (in the coffee can), and ask students how much of the paper exposed to air. They should say all of it.
- Now crumple the paper into a small ball, and ask students how much of the paper is exposed to the air. Make sure they understand that the crumpled paper has a smaller surface area than the flat paper.

Tell students that the next demonstration will illustrate the effect of surface area or particle size on the rate of a reaction.

**Materials needed for the Dust in a Flame Demonstration** are in the Coffee Can which contains:

1 box of matches   1 vial of lycopodium “dust” powder
1 pipette (jumbo size) 1 tea light candle
1 aluminum pan

Your Notes:
- Show the students the lycopodium "dust" powder.
- Place a small pile of powder on the aluminum pan and attempt to light it with a match. (Depending on how long the match is held to the powder - it will either not burn or will burn enough to char a little.)
- Light the tea candle and place it on the aluminum pan.
- Load the pipette with a small amount of dust powder (enough to fill the tip). **Do not turn the pipette upside down.** There must be powder at the tip of the pipette for this to work.
- Hold the pipette so the tip is above the flame and squeeze the pipette bulb to release the lycopodium powder into the flame.
- There will be a flash of fire.

Ask students: Why was there a flash of fire?

*More of the surface of the particles is exposed to the oxygen in the air when the particles are sprayed into the flame. This causes a flash of fire that indicates more rapid burning (combustion) of the lycopodium powder.*

**Explanation:** When the powder is in a pile, it will not light. Oxygen cannot get inside the pile to react with enough particles of powder; it can only react with the particles on the outside of the pile. When the powder is suspended in the air, it has more surface area than when it was in a pile. This is because the particles are extremely small. When they are sprayed into the air near the flame, the particles are spread out so the oxygen in the air reaches more particles at the same instant – hence more particles are burning at the same time, and you see a big flash of flame. (Lycopodium powder is a dried-up moss. It is used for this type of demonstration because the powder has extremely small particles.)

**V. The Effect of Surface Area on the Rate of a Reaction: Experiment**

- Ask students to use what they learned about surface area in the last experiment to suggest ways to increase the surface area of the tablets to speed up the rate of the reaction.

You may have to guide this a little, but students should say that crushing the tablet will give a faster reaction because it has a larger surface area. Make the comparison with the lycopodium dust powder that failed to ignite in a clump. The tablet is in a clump. How can we change that?

**Give each GROUP OF 3 the following:**

2 10 oz dry cups, 1 packet of 2 effervescent tablets, 1 small Ziploc bag

(Students should already have two 3.5 oz cups that they used in Section II, the bottle of water, a pair of scissors, and a plate.)

- Place the two 3.5 oz measuring cups on the plate.
- Fill the two cups to the mark using the bottle of water.
- Carefully cut open the packet of effervescent tablets and remove them from the packet.
- Place one whole tablet in the bottom of one of the **dry** 10 oz plastic cups.
- Place the other tablet in a small Ziploc bag, seal the bag, and crush the tablet by tapping on the bag with the water bottle or the palm of their hand.
- Shake all of the crushed tablet into one bottom corner and cut the other bottom corner off.

Your Notes:
Then pour the crushed tablet through the bottom cut corner into the other dry 10 oz plastic cup.

Ask students to observe the two tablets now and tell which tablet has more surface area. *The crushed tablet - more of the inside surface of the tablet is now exposed.* Additionally, *the crushed tablet takes up more space by covering the base of the cup than does the whole tablet.*

VSVS team members should make sure groups are ready by asking two students from each group to hold a cup of water in a “ready” position over either the cup with a whole tablet or the crushed tablet. Tell them they should be ready to pour all the contents into the cup on the count of 1,2,3, Go.

Make sure students realize the importance of making sure they add the contents at the same time and from the same height just above the cup containing the Alka Seltzer solid. If a reaction takes a certain amount of time to occur, it is very important that the start times be the same so that comparisons can be made without the error resulting from different initiation times.

Then one of the VSVS team says "1,2,3, Go,” and on “Go,” the students should add all the water from their cups.

Record the results.

Ask students: Which tablet had a faster reaction?
*Bubbles of carbon dioxide come off more quickly from the crushed tablet than from the whole tablet.*

Ask students: How does surface area affect the rate of a reaction?
*A larger surface area will increase the rate of reaction.*

VI. Dust Can Explosion: Demonstration

**Caution:** This experiment is loud and sometimes propels the lid of the coffee can in the air. Be sure the can is some distance away from the nearest students before you do this experiment!

- Show students the "dust can."
- Light the tea light candle and place it in the coffee can.
- Load the pipette with a small amount of dust powder (enough to fill the tip). DO NOT turn the pipette upside down. There must be powder at the tip of the pipette for this to work.
- Show the students the hole in the side of the can.
- Ask students to predict what will happen when you 'blow' the dust into the can.
- Holding the pipette at an angle (aiming down with about a 30° angle), place the pipette in the hole (make sure the pipette is snug) and make sure that the pipette and flame are aligned.
- Place the lid on the can. **Do not do this until now – the flame will go out before you can get the powder into the can.**

Your Notes:
- Squeeze firmly on the pipette, and leave the pipette in the hole after squeezing.
- There will be a flash of fire, a loud explosion, and the lid will blow off the can.

Ask students: Why was the reaction quicker and bigger when the dust was blown around in the can rather than in an open flame?

**Note:** If the explosion does not happen on the first try, please try again. Some groups have to try this three or four times to achieve the desired results. The students love to see this more than once and it shows them that perseverance pays off.

**Explanation:** The dust can explosion is a dramatic illustration of the effect of surface area on the rate of reaction. The chemical reaction is the same as any combustion reaction of any organic fuel - wood, coal, gasoline, natural gas. The contents of these fuels are carbon compounds which combine with oxygen to give carbon dioxide and water vapor. If these gases are confined, an explosion will occur because the gases take up much more volume than the solid fuel. Some explosions are useful. For example, the internal combustion engine in a car works by small explosions set off by sparks from the spark plugs in each cylinder which drives the pistons. Other explosions can be disastrous - such as a flour mill explosion. The dust can explosion is a safe, small scale illustration of what happens in a flour mill explosion.

The dust can explosion illustrates why workers in grain elevators, saw mills, and flour mills have to be very careful about sparks. A spark can ignite burnable dust in the air to produce a large explosion. Show students the picture of a dust explosion in a rubber factory.

**VII. Effect of a Catalyst**

**Learning Goals:** Students understand what a catalyst is and know that it is not used up or changed in a reaction.

**Materials:**
1 demo bag containing:
1 clear 6-oz screw-cap jar one-third full of 1.5% hydrogen peroxide
1 small container of manganese dioxide
1 small plastic scoop
2 splints
1 box of matches
1 bottle hydrogen peroxide
1 pair tongs

Ask students: What is a catalyst?
A catalyst is a substance that speeds up or slows down a chemical reaction but is not changed by the reaction.

Show the students the bottle of hydrogen peroxide.
Ask students what they know about hydrogen peroxide (H₂O₂).
Some students will know that hydrogen peroxide is often put on cuts and that it bubbles up. Someone might know that it is H₂O₂.
Include the following information in the discussion:
- Tell students that hydrogen peroxide (H₂O₂) will chemically decompose (break down) into oxygen gas (O₂) (yes, the glowing splint test will work!) and water (H₂O).

**Your Notes:**
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Hydrogen peroxide is sold in brown bottles because it will decompose in the presence of light. Hydrogen peroxide bottles are dated because even in a brown bottle, hydrogen peroxide will decompose over time.

Tell students that the decomposition of hydrogen peroxide will speed up if a catalyst is added to the hydrogen peroxide.

**Demonstration of Manganese Dioxide as a Catalyst:**

- Two VSVS members should work together on this demonstration.
- Remove the clear jar containing hydrogen peroxide from the demo bag.
- Show the bottle to the students, telling them that it is a 1.5% solution of hydrogen peroxide.
- One VSVS member should unscrew the cap on the jar, set the cap down on a table, and continue holding the jar while another VSVS member takes the small spoon and gets a level spoonful from the container of manganese dioxide.
- A second VSVS member should light a splint with a match and shake it out until it is glowing without flaming.
- Tell students to watch what happens when the spoon of manganese dioxide is added to the jar. As soon as you see vigorous bubbling with what appears to be a gas coming from the bottle, insert the glowing splint into the top of the jar. Observe that it bursts into flame. Repeat the glowing splint test several times while bubbles of gas are being given off.
- As soon as bubbling ceases (about five minutes – you can wait until after students do the next part of the lesson), screw the cap back tightly on the jar and place it and the small plastic scoop back in the demo bag. Then put the demo bag back in the kit.
- Ask students: What gas caused the glowing splint to burst into flame? Oxygen. *(Hydrogen bubbles would put the flame out).* Explain to the students that the Manganese dioxide is a catalyst which breaks down hydrogen peroxide faster into Oxygen and water. Because fire burns oxygen, this creates enough oxygen to relight the flame, even though before there wasn’t enough.

Point out to the students that the manganese dioxide still looks the same – catalysts are not changed to something else nor are they consumed during the reaction.

**For VSVS Information Only:** Many chemical reactions are slow because they involve several intermediate steps that are of high energy. A good analogy is the difference between driving over a mountain or driving through a tunnel in the mountain. It takes less time to drive through a tunnel than over the top of the mountain. The regular chemical reaction goes through an intermediate state of high energy like going over a mountain while the catalyst provides a new pathway of lower energy for the chemical reaction, similar to going through a tunnel in the mountain.

Enzymes bind their substrates (in this case H₂O₂) into a cavity before catalyzing a reaction. Once the substrate is in the cavity, binding between the enzyme and the substrate weaken substrate bonds, making it easier for new bonds to form. The best analogy is the Venus flytrap. This plant traps an insect by folding around it. The folding is triggered by the presence of the insect, just as the folding of the enzyme is triggered by the presence of the substrate. After the catalyzed reaction is complete, the enzyme opens up again to let the products leave and to prepare for the next substrate molecule. Your body has thousands of enzymes that catalyze reactions, including catalase in the blood that catalyzes the breakdown of hydrogen peroxide that is formed in some biological reactions and must be decomposed to avoid harmful effects on the body.

Another example of an enzyme at work is the breakdown of starches to simple sugars. The next time you are chewing a cracker, see if you can tell whether the initial salty taste turns to a sweet
taste. The saliva in your mouth causes a chemical breakdown of the starch in the cracker as the cracker is chewed by the mouth. The enzyme amylase begins breaking down the starch in the cracker to individual sugar molecules so the cracker begins to taste sweet.

VIII. Review (Time Permitting)

Review the vocabulary words on the board. Then review the factors that affect the rate of chemical reaction.

In each activity one of the factors that influence the rate of chemical reactions was varied while the others were held constant.

1. Ask students: What effect did temperature have on the rate of reactions?
   *The lower the temperature, the slower the reaction. The higher the temperature, the faster the reaction.*

2. In the second student activity, the concentration of vinegar was varied while the temperature was held constant.
   Ask students: What effect did concentration have on the rate of the reaction?
   *The higher the concentration, the faster the reaction occurred.*

3. In the third student activity, the temperature of the water was constant, and the surface area was varied by using a whole tablet and a crushed tablet.
   Ask students: What effect did surface area have on the rate of the reaction?
   *In this case, the crushed tablet reacted faster because of the higher surface area of the particles as compared to the whole tablet.*

4. In the fourth student activity, the effect of a catalyst was studied at constant temperature, by adding the catalyst to the hydrogen peroxide.
   Ask students: What effect did the catalysts have on the rate of decomposition of hydrogen peroxide?
   *Manganese dioxide caused the decomposition of hydrogen peroxide to be faster as indicated by the bubbles of gas given off when the catalyst was added.*

Return of the Kit: It is important that all items be returned to the kit box. Be sure to collect all instruction sheets (in sheet protectors) and put them back in the kit box. Be careful not to place wet objects in kit.

Make sure the cap is on the demo bottle of hydrogen peroxide and put it back in the kit, not in the trash bag. Kits should be returned to SC 5234 as soon as you return to campus from the school.

Lesson written by Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University

ANSWER SHEET
Rates of Reaction

Name _____________________________________

Vocabulary words: rate, concentration, chemical reaction, catalyst, surface area,

II. Effect of Temperature – Ice water vs. room temperature water

Which was faster? ______ Room Temperature ______ How can you tell? ______ Bubbles come off faster

Which one finished before the other? __ Room Temperature

How could we change the temperature to make the reaction occur even faster? Heat the water to a higher temperature before adding the tablet. The higher the temperature, the faster the reaction will occur.

III. Effect of Concentration – weak vs strong vinegar

Which was faster? strong. How can you tell? Bubbles come off faster

V. Effect of Surface Area

1. Demonstration of lycopodium “dust” powder (dried-up moss)

Why was there a flash of fire when a pipette of lycopodium powder was sprayed across a burning match, but only some charring occurred when a burning match was held close to a pile of lycopodium powder?

More of the surface area of lycopodium powder was exposed to the oxygen in the air.

2. Which tablet reacts faster – crushed or whole? The crushed tablet reacts faster. Why?

The smaller particles in the crushed tablet expose more of the surface area to react with the water.

3. Why was there an explosion when a pipette of lycopodium powder was sprayed into the coffee can with a lit tea candle?

The gases produced when the lycopodium powder burned built up enough pressure to blow off the lid.

4. What gases are produced when lycopodium powder is burned? Carbon dioxide and water vapor (any organic materials – lycopodium powder, wood, coal, gas – produce carbon dioxide and water gases when they burn).

VI. Catalysts

What happens when manganese dioxide is added to hydrogen peroxide? The solution foams vigorously, giving off bubbles of a gas.

What gas is indicated by the glowing splint test? Oxygen

Does manganese dioxide look like it has changed? No
OBSERVATION SHEET – Rates of Reaction

Name ____________________________

Vocabulary words: rate, concentration, chemical reaction, catalyst, surface area, enzyme

II. Effect of Temperature – Ice water vs. room temperature water
Which was faster? _________________ How can you tell? ______________________________

How could we change the temperature to make the reaction occur even faster? ________

III. Effect of Concentration – weak vs. strong vinegar
Which was faster? _________________ How can you tell? ______________________________

IV. Effect of Surface Area
1. Demonstrations of lycopodium “dust” powder (dried-up moss)
Why was there a flash of fire when a pipette of lycopodium powder was sprayed across a burning match, but only some charring occurred when a burning match was held close to a pile of lycopodium powder?

2. Which tablet reacts faster – crushed or whole? ________________________________
Why? ________________________________

3. Why was there an explosion when a pipette of lycopodium powder was sprayed into the coffee can with a lit tea candle?

IV. Catalysts
What happens when manganese dioxide is added to hydrogen peroxide? ________________

What gas is indicated by the glowing splint test? ________________

Does manganese dioxide looks like it has changed? ________________

Try putting a potato slice in some hydrogen peroxide at home and see if the potato slice looks any different after one day. Potatoes, and other vegetables and meats contain an enzyme catalase that act as a catalyst to decompose hydrogen peroxide in the body.