5^{th} Grade

Spring 2019 Lesson Plans

Vanderbilt Student Volunteers for Science

http://studentorg.vanderbilt.edu/vsvs/

VOLUNTEER INFORMATION

Team Member Contact Information

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 Educational Coordinator:

Paige Ellenberger 615-343-4379
paige.ellenberger@vanderbilt.edu **VSVS Office:** Stevenson 5234

Co-Presidents:	Eric Zhang	eric.zhang@vanderbilt.edu
	Vineet Desai	vineet.desai@vanderbilt.edu
Secretaries:	Gabriela Gallego	gabriela.l.gallego@vanderbilt.edu
	Emily Chuang	emily.a.chuang@vanderbilt.edu

Vanderbilt Protection of Minors Policy: As required by the Protection of Minors Policy, VSVS will 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:

- The lessons are online at: http://studentorg.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 Paige 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 N_2).
- 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.
- There are two 20 minute parking spots in the loading dock behind Stevenson Center. Please do not use the handicap spaces – you will get a ticket.

While you're there – Just relax and have fun!

February						
SUN	MON	TUES	WED	THU	FRI	SAT
					1	2 New member training
3	4	5 New member training	6	7 Team leader training	8	9
10 Team leader training	11 Team training Lesson 1 / 5th-7th Alt training	12 Team training Lesson 1 / 5th/7th Alt training	13 Team training Lesson 1 / 5th/7th Alt training	14 Team training Lesson 1 / 5th/7th Alt training	15 Team training Lesson 1 / 5th/7th Alt training	16
17	18 Teams go out (Lesson 1) / Alt 6th-8th team training	19 Teams go out (Lesson 1) / Alt 6th-8th team training	20 Teams go out (Lesson 1) / Alt 6th-8th team training	21 Teams go out (Lesson 1) / Alt 6th-8th team training	22 Teams go out (Lesson 1) / Alt 6th-8th team training	23
24	25 5th-7th team training / Alt Teams go out (Lesson 1)	26 5th-7th team training / Alt Teams go out (Lesson 1)	27 5th-7th team training / Alt Teams go out (Lesson 1)	28 5th-7th team training / Alt Teams go out (Lesson 1)		

March						
SUN	MON	TUES	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11 6th-8th team training	12 6th-8th team training	13 6th-8th team training	14 6th-8th team training	15 6th-8th team training	16

17	18 Teams go out (Lesson 2)	19 Teams go out (Lesson 2)	20 Teams go out (Lesson 2)	21 Teams go out (Lesson 2)	22 Teams go out (Lesson 2)	23
24	25 Teams go out (Lesson 3)	26 Teams go out (Lesson 3)	27 Teams go out (Lesson 3)	28 Teams go out (Lesson 3)	29 Teams go out (Lesson 3)	30

April						
SUN	MON	TUES	WED	THU	FRI	SAT
31	1 Teams go out (Lesson 4)	2 Teams go out (Lesson 4)	3 Teams go out (Lesson 4)	4 Teams go out (Lesson 4)	5 Teams go out (Lesson 4)	6
7	8 Make-up week	9 Make-up week	10 Make-up week	11 Make-up week	12 Make-up week	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

CLASSROOM ETIQUETTE

Follow Metro Schools' Dress Code!

- No miniskirts, shorts, or tank tops.
- Tuck in shirts if you can.
- Please dress appropriately.

Metro student standard attire guideline:
http://jtmoorems.mnps.org/pages/JohnTrotwoodMooreMiddle/About_Our_School/8998762518461552450/Dress_Code

COLLEGE Q&A SESSION

VSVS members should be candid about their experiences and emphasize the role of hard work and a solid body of coursework in high school as a means to get to college.

- Email the teacher prior to the first lesson.
  - They may want to have the students write down questions prior to your lesson.
  - They may also want to have a role in facilitating the discussion.
- Finish the experiment of the day and open up the floor to the students.
- Remind them of your years and majors and ask if they have specific questions about college life.
- If they are shy, start by explaining things that are different in college.
  - Choosing your own schedule, dorm life, extracurricular activities, etc.

- Emphasize the hardworking attitude.

The following are some sample questions (posed by students):

- When is bedtime in college? Does your mom still have to wake you up in college?
- How much does college cost?
- What do you eat in college and can you eat in class in college?
- How much homework do you have in college?

DIRECTIONS TO SCHOOLS

H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD **615-353-2020**

HG Hill School will be on the right across the railroad lines.

HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE **615-329-8160**

The parking lot on the left to the Johnston Ave.

J.T. MOORE MIDDLE SCHOOL: 4425 GRANNY WHITE PIKE **615-298-8095**

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: 713 RAMSEY STREET **615-271-3222**

Going down Ramsey Street, Meigs is on the left.

ROSE PARK MAGNET SCHOOL: 1025 9th AVE SOUTH **615-291-6405**

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 **615-298-8425**

Parking is beside the soccer field, or anywhere you can find a place. Enter through the side door.

EAST NASHVILLE MAGNET MIDDLE SCHOOL: 2000 GREENWOOD AVE **615-262-6670**

MARGARET ALLEN MIDDLE SCHOOL: 500 SPENCE LN **615- 291- 6385**

From West End down Broadway, take 1-40E to exit 212 Rundle Ave. Left on Elm Hill to Spence Lane.

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

http://studentorg.vanderbilt.edu/vsvs

Properties of Iron

Mini lesson for Spring 2019

Goal: To learn the difference between elements and compounds by studying the different forms of iron. Fits Tennessee standard : 5.PS1.4

VSVSer Lesson Outline:

_________**I. Introduction: Elements, Compounds, and Mixtures**
Discuss elements, compounds, and mixtures and focus on iron.

_________**II What are the Physical Properties of Elemental Iron and Iron Oxide?**................
Students examine the physical properties of iron and iron oxide, including the magnetic properties of elemental iron using a magnet.

_________**III. Chemical Properties of Iron – Rusting**
Students understand the nature of oxidation and how it is a chemical property of elements and compounds.
A. Students observe rusting in a chemical hand-warmer.
B. Students use salt, iron filings and peroxide to observe "speed" rusting.
C. Students recheck the hand-warmer and their experiment.

_________**VI. Review.**

Complete teacher/school information on first page of manual.

1. Make sure the teacher knows the VSVS Director's (Paige Ellenberger) office number and email (in front of manual).
2. Exchange/agree on lesson dates and tell the teacher the lesson order (**any changes from the given schedule need to be given to Paige in writing (email)**).
3. Since this is your first visit to the class, take a few minutes to introduce yourselves. Mention you will be coming three more times to teach them a science lesson.
4. Do the experiment with the classroom, and leave 10 minutes at the end to discuss aspects of college life with them. Some topics that could be included are in the manual.

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.

Materials
1bagcontaining Iron element, compound and mixture models
15 bags containing:
- 1 oz sealed wide-mouth bottle of Iron metal
- 1 oz sealed wide-mouth bottle of iron oxide- Fe_2O_3
- 1 oz sealed wide-mouth bottle of iron filings
- 1 white Teflon magnet

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

15 plates
15 ziploc bags containing 1 oz wide-mouth bottle of iron filings, 1 oz wide-mouth bottle of salt and 1 plastic scoop
1 bag containing 30 1oz cups with cotton balls
1 plastic bin (lined with aluminum foil) containing 15 dropper bottles of water and hydrogen peroxide

1 trash bag
1 binder containing 30 observation sheets, 15 instruction sheets, 16 periodic tables (1 per pair), and 1 ppt

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 the difference between an element and a compound?
2. What is oxidation and what are some real-world examples of it?
3. Why does hydrogen peroxide cause iron to rust faster?

2. Use these fun facts during the lesson:

- Iron is a mineral that is found in every cell of the body. The most important role of iron in the body is in respiration. Iron binds oxygen in the blood, allowing an adequate supply of oxygen to be carried throughout the body from the lungs.
- Animals and plants require iron. Plants use iron in chlorophyll, the pigment used in photosynthesis. Humans use iron in hemoglobin molecules in blood.
- Iron is the sixth most abundant element in the universe and the fourth most abundant element in the earth's crust. It comprises about 5.6% of the earth's crust and almost all of the earth's core.
- The element symbol for iron is Fe, which comes from the Latin word for iron, "ferrum".
- Steel is made from iron and carbon, which makes it harder than iron. Steel can also be galvanized to prevent iron oxide from forming (i.e. rusting). This process usually involves a very thin layer of zinc being applied to the surface.

Note: The magnets used in this lesson are expensive. Please check carefully to be sure all magnets are returned.

<u>Unpacking the Kit:</u>

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. Elements, Compounds, and Mixtures

16 periodic tables in page protectors (1 per pair)
1 bag containing iron element, compound, and mixture models
15 bags containing 1 oz sealed wide-mouth bottle of Iron metal, 1 oz sealed wide-mouth bottle of iron oxide- Fe_2O_3, 1 oz sealed wide-mouth bottle of iron filings, 1 white Teflon magnet
30 observation sheets and 16 instruction sheets

For Part II - What are the Physical Properties of Elemental Iron and Iron Oxide?

Same as above.

For Part III. Chemical properties of Iron – Oxidation (Rusting)

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. Oxidation of iron experiment

15 plates
15 ziploc bags containing 1 oz wide-mouth bottle of iron filings, 1 oz wide-mouth bottle of salt and 1 plastic scoop

Your Notes:

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1 bag containing 30 1oz cups with cotton balls
1 plastic bin containing dropper bottles of water and hydrogen peroxide

I. Introduction: Elements and Compounds.

Learning Goals: To help students identify the key factors that differentiates elements and compounds.

Why is the science in this lesson important?

Our body needs certain vitamins and minerals to survive, and iron is an important mineral required for adequate delivery of oxygen to different tissues. However, iron deficiency is also the most common and widespread nutritional deficiency in the world. Giving newborns with low birth weights iron supplements helps prevent behavioral and neurological problems later in life. The importance of iron in diet is still being researched, and new functions of iron are still being discovered!

Materials

16 periodic tables in page protectors (1 per pair) – in binder
Iron element, compound, and mixture models

Write the following on the board:

element, compound, mixture, **elemental iron**, **Fe, Fe_2O_3**

Hand out the large periodic tables in page protectors.
Ask students: What is the difference between an element and compound? (Keep the discussion as simple as possible.)

- **Elements** are the building blocks of matter. Use the periodic table while you discuss elements.
  - Show students the element models. Explain that there is only one kind of atom here.
    - One bag contains only red balls. The **red** balls represent **iron**.
    - The other bag contains only **blue** balls which represent **oxygen**.
  - Show students the placement of iron and oxygen in the periodic table.

- **Compounds** are made up of two or more **elements that are chemically bonded together.**
  - Show students the rust (iron oxide) model. Explain that there are two kinds of atoms here and that they are connected to one another.
    - The red atom is iron and the blue atom is oxygen.
    - Tell students that there are two iron atoms for every three oxygen atoms.
    - Other examples of compounds include water (H_2O), carbon dioxide (CO_2), table sugar ($C_{12}H_{22}O_{11}$), and table salt (NaCl).

Tell the students that in today's lesson you will be studying some physical and chemical properties of elemental iron**.**

Give each pair a bag containing:

1 oz sealed wide-mouth bottle of Iron metal
1 oz sealed wide-mouth bottle of iron oxide- Fe_2O_3
1 oz sealed wide-mouth bottle of iron filings

Your Notes:

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1 white Teflon magnet

Give each student an observation sheet and an instruction sheet.

Tell the students to look at the labels on the bottles.

Ask students:

- How can we tell if a chemical is an **element or a compound**? *The formula for an element contains only one atomic symbol, whereas the formula for a compound contains more than one atomic symbol.*
- Which containers have the element? *Fe (Iron Filings and iron metal)*
- Which container has the compound? Fe_2O_3 *(rust)*
    - Point out to students that iron oxide is a compound because it has two different elements - iron, and oxygen - which are chemically combined. The small numbers give the ratio of elements in the compound.
    - Ask students what happens when an iron shovel is left outside? *When it is left outside, the iron reacts with oxygen to form rust, which is iron oxide.*

Tell the students:

- Every compound has its own properties, which are different from the properties of the elements that make up the compound. In their tests today, the students will study the physical and chemical properties of elemental iron and iron in iron oxide (rust).

II. What are the Physical Properties of Elemental Iron and Iron Oxide?

Learning Goals: To help students characterizes elements and compounds based on physical properties.

A. Physical Properties of Elemental Iron and Iron Oxide.

  a. **Ask students: What are some physical properties of elemental iron?** *Iron is a metal. It is hard. It is shiny. It is attracted to magnets*

  b. **Ask students: What are some physical properties of the compound iron oxide?** *Iron oxide is a powder. It is red. It is not attracted to a magnet.*

- Tell the students to put the magnet on the **outside** of the iron metal and the iron filings container, and to slowly move it up the side or across the vial. What happens?
- Have them repeat this with the iron oxide.
- Emphasize that the physical properties of elemental iron and iron compounds are not the same.
- Have students check the appropriate blank for Part II on the observation sheet.

III. Chemical Properties of Iron – Oxidation (Rusting)

Learning Goals: To assist students in understanding the nature of oxidation, and how it is a chemical property of elements and compounds

Ask students if they know what **oxidation** means? *Oxidation usually occurs when an element or compound combines with* ***oxygen****.*

What are some things that **oxidize**?

Cut fruits oxidize – apples turn brown after they have been cut and left exposed to air.
Copper oxidizes and becomes a dull color (new pennies are shiny; older ones are dull).
Silver becomes "tarnished" and black when it oxidizes.
Iron is oxidizing when it rusts and turns a reddish color.

This is a chemical property of iron.

Your Notes:

Rust is the common name for a very common compound, iron oxide. Rusting is a very slow process which takes place over several weeks or months.
Ask students to name things that rust? *Anything made of iron, that is left outside (in the rain) will rust faster than things kept dry and inside. Examples may include gardening tools, bicycles, anything with exposed iron.*

A. Commercial HotHands Pack.
Show the students one of the commercial HotHands. Ask the students if anyone has used one? Campers or hunters use these to keep their hands warm in cold weather.

Give each group of 3-4 students a HotHands pack and tell them to remove the plastic covering and touch the pack so that they can feel that it is at room temperature.
Tell one member in the group to shake it to activate it and then set it aside until after the next experiment has been set up.
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.

How do HotHands work?

- 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 same reaction as rusting (iron + oxygen + water). The iron + oxygen + water reaction in the HotHands pack is 1000 times faster than normal rusting.

Have students go on to Part B while they are waiting for the hand-warmers to get warm.
Ask students if they have ever seen iron rust in a few seconds? *Probably not!*
Tell the students they are going to put some chemicals together that will cause rusting in just a few minutes.

B.   Experiment - Rusting of Iron Filings

Give each student goggles.
Hand out the following materials to each pair,

1 plate
1 ziploc bag containing:
1 1 oz wide-mouth bottle of iron filings
1 1 oz wide-mouth bottle of salt
1 plastic scoop
2 1oz cups with cotton balls
1 dropper bottle containing water
1 dropper bottle containing hydrogen peroxide

Tell students to:

1. Note – the reason for using the cotton is to make the color change due to rusting more obvious.
2. Sprinkle iron filings on top of the cotton in each cup (a small scattering is all that is needed).

Each piece of cotton will now be treated differently.

Your Notes:

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Tell students to

3. Add a **squirt of water** on top of the filings in the 1st cup.
4. Add a sprinkle of salt and a **squirt of hydrogen peroxide** on top of filings in the 2nd cup.

Have the students observe the 2 cups for a few minutes and then ask them what differences they can see. Have students answer the questions in Part III of the observation sheet. Answers may include:

The cotton containing iron and water (cup 1) does not have orange coloring.
The cotton containing the hydrogen peroxide and salt (cup 2) will have some orange color (rust).

Set aside to observe again later.

Explanation
For iron to rust & become iron oxide, 3 things are required: **iron, water and oxygen.**
The equation for oxidation of iron is: $4Fe + 3O_2 \text{ -----> } 2Fe_2O_3$
Hydrogen peroxide is a good source of oxygen.
Iron can rust without salt being present, but it will make rusting even faster (it is a catalyst). Iron objects close to the ocean rust faster. Cars rust faster when we salt the roads in the winter to melt ice.

Write the formulas for hydrogen peroxide and water on the board: H_2O and H_2O_2 to show the students that there is more oxygen ("O") in the peroxide.

Ask students which of the 2 cups had the best conditions for rusting? *Cup 2, because the hydrogen peroxide could supply more oxygen than just water (as in cup 1), and salt speeds up rusting.*

C. Checking the HotHands Hand Warmer

- Have the students feel the hand warmer. (It should feel warm.)
- The oxygen in air reacted with iron to form iron oxide with the **release of heat**.
- Tell students this is an example of an 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.)*

For VSVS information only:
Why did the temperature change? *The chemical reaction producing the iron oxide is an exothermic reaction, which means that it gives off energy in the form of heat.*
In everyday life, why don't objects that rust get hot? *Iron filings have a large surface area in contact with the water or salt, so the rusting occurs very rapidly. Most rusting objects in everyday life, such as cars, shovels, etc., have a smaller surface area that is rusting and thus will not rust nearly as fast and therefore will not generate the heat observed in your experiment.*
How does rusting generate heat? *Changes in the energy held by chemical bonds in the oxidation of iron yield a net loss of energy from the reactants, and this net loss escapes to the surroundings where it is felt as heat.*

Your Notes:

IV. Review and Clean-up.

Review the vocabulary words and the responses to the questions on the Observation Sheet.
Students can check the cups with iron filings to observe the reactions again.

Return all cups with used iron filings in the plastic trash bag.
The HotHands hand-warmer can be left in the classroom with the teacher or the students, returned to the VSVS lab or kept by the VSVS members.

Lesson written by: Dr. Melvin Joesten, Emeritus Professor, Vanderbilt University
Pat Tellinghuisen, Program Coordinator of VSVS 1998-2018, Vanderbilt University
Heather Day, Program Assistant for VSVS, Vanderbilt University

Your Notes:

Properties of Iron

Observation sheet

NAME ____

VOCABULARY WORDS:
element, compound, mixture, elemental iron, Fe, Fe_2O_3

I. Elements, Compounds, and Mixtures
Which containers have the element iron? *Fe (Iron Filings and iron metal)*
Which container has the compound? *Fe_2O_3 (rust)*

II Test for Elemental Iron Using a Magnet – a physical property
Circle the correct answer.
Are the **<u>elemental</u>** iron filings and iron metal magnetic? Yes No

Is the **<u>compound</u>** iron oxide magnetic? Yes No

Is magnetism a physical or chemical property? Physical Chemical

IIIA. Commercial HotHands Pack.

HotHands ingredients: Iron Powder, Water, Salt, Activated Charcoal, Vermiculite

For iron to rust & become iron oxide, 3 things are required: **iron, water and oxygen.**
The equation for oxidation of iron is: $4Fe + 3O_2 \text{ -----› } 2Fe_2O_3$

What element is missing in order for the iron to oxidize? _______________
IIIB. Rusting – a chemical property of Iron

In cup 1, water H_2O) is added to the iron filings. What happens?

____

In cup 2, hydrogen peroxide (H_2O_2) and salt are added to the iron filings. What happens?

____

Which cup had more oxygen available?

What happened to the HotHands Pack after it was activated? ________________________________

Properties of Iron
ANSWER OBSERVATION SHEET

NAME ____

VOCABULARY WORDS:
element, compound, mixture, elemental iron, Fe, Fe_2O_3

I. Elements, Compounds, and Mixtures

Which containers have the element iron?
Fe Iron Filings and Fe Iron Metal)
Which container has the iron compound?
Fe_2O_3 (rust)

II. Test for Elemental Iron Using a Magnet – a physical property

Are the **elemental** iron filings and iron metal magnetic? _X__ Yes ____ No
Is the **compound** iron oxide magnetic? ____ Yes _X__ No

Is the property of magnetism a physical or chemical property (circle the answer)?
physical ~~chemical~~

IV. Rusting – a chemical property of Iron

What happened in cup 1? *Nothing*

What happened in cup 2? *The iron filings turned orange. They rusted.*

What happened to the Hothands Pack after it was activated? *It became warmer.*

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorg.vanderbilt.edu/vsvs

Chromatography

Spring 2019

Goal: To demonstrate a technique or process for separating mixtures that is used by biologists, chemists, clinical scientists, and forensic scientists (detectives).
Tn State Stds: 5PS1.4

Lesson Outline
I. A. What is a Mixture?
Explain to the students that there are 2 types of mixtures – homogeneous and heterogeneous. And show examples of both.
Discuss methods used to separate mixtures.
B. Making a Homogeneous Mixture
Explain to the students that chromatography is a process for separating mixtures. In today's lesson, paper chromatography will be used to separate water-soluble inks into their different colors, starting with the separation of green into blue and yellow.
II. Chromatography Using a Green Pen to separate a Homogeneous Mixture
Show students the proper procedure for setting up a chromatography experiment, using a 16 oz cup, a stick, green pen, and a paper strip. Each student pair will do this.
III. Forensic Chromatography
Each pair does a chromatogram of one of the four pens to help determine which pen was used to write a ransom note. After the chromatograms are finished, ask the students to compare their chromatograms with the chromatogram prepared from the guilty person's pen to determine who is the guilty person.
IV. Review

Materials
3 250 mL bottles filled with water (use to put water to the mark (about 25-30 mL) into the 16-oz cups)
1 bag of colored balls
1 jar sand and iron filings and cow magnet
1 bag containing 1 125cc jar of blue water, 1 125cc jar yellow water (1/4 filled)
1 bag containing: 16 rolls of clear tape
1 bag containing 16 wooden sticks
1 bag containing 5 green pens
1 bag containing 16chromatography strips with green horizontal line drawn 2 cm from the bottom of the strip
1 bag containing 16chromatography strips (horizontal pencil line is drawn 2 cm from the bottom of the strip)
16 16 oz. clear plastic cups, marked at the 25 - 30 mL level
1 large bag containing 15 black pens labeled with suspects initials (PC, PS, JF or MM)
16 prepared laminated chromatograms from the "guilty" person's pen (PC)
16 prepared laminated chromatograms from the 4 different pens
16 sheets of paper towel

SET UPS FOR LESSON:

While a VSVS member does the Mixing Colors demonstration:

1. Another member pours water into enough 16 oz cups to the marked level for pairs in the class, plus one for VSVSers to do demonstration
2. Remaining members will attach the **chromatography paper already marked with the green pen to the sticks (see instructions on how to do this).**
   Hold the paper strip so that the top edge of the paper is even with the top edge of the wooden

stick.
Tear a small piece of tape and tape the paper strip to the wooden stick so that the tape goes around the stick and is taped to both the front and the back of the paper strip.

Put the following vocabulary words on the board:
Mixture, chromatography, chromatogram, capillary action, forensic chromatography

Unpacking the kit:

1. What is a Mixture?

1 bag of colored balls,
1 8 oz jar with sand/iron filings mixture and a cow magnet

B. Demonstration – Making a Homogeneous Mixture

1 bag containing: 1 jar blue water, 1 jar yellow water (each about ¼ filled)

II. Using Chromatography to Separate a Homogeneous Mixture (using a green Pen)

Materials: (1 set is for VSVS to use as demo)
16 16 oz. clear plastic cup with water to the mark (about 30 mL.)
5 green pens
16 chromatography strips that already have the green pen trace don the horizontal line AND prepared by VSVSers so that the paper is already attached to wood stick

II.Forensic Chromatography

Distribute the following materials to each **pair:**
1 piece of chromatography paper
1 16 oz clear plastic cup –students already have
1 stick – students already have, but the green chromatogram needs to be removed.
1 roll of clear tape
1 paper towel
Student pairs will need to share the black pens and tape
Distribute the 16 laminated chromatograms

1. What is a Mixture?

- **Mixtures** are made up of **two or more different elements or compounds** which can be separated by physical means.
  - Show students the bag of mixed balls. Explain that each differently colored ball represents an element or compound.
    - The balls are not connected, so they are a mixture.
    - Examples of mixtures include salt in water, air, soil, and sand. Mixtures can be made with any combination of phases of matter: solid in solid, (sand and iron filings), solid in liquid, (salt in water), gas in liquid (carbon dioxide bubbles in water) etc
- There are 2 types of mixtures: heterogeneous and homogeneous
  - In heterogeneous mixtures, the substances are unevenly mixed and you can see them.
  - In homogeneous mixtures, the different substances are evenly mixed so that you cannot see them. Mixing colored solutions is an example.

Your Notes

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A. Demonstration: Using the magnetic property of iron to separate a heterogeneous mixture.

Materials

1 8 oz jar with sand/iron filings mixture and a cow magnet

Tell students to look at the jar of sand.

- Why do you think it is a mixture? *Because it contains different kinds of particles*.
  - Tell the students that sand is a collection of fragments of minerals, shells, fossils and organic matter. Sometimes it contains iron in the form of magnetite, which is magnetic. This is called Ironsand and can be found worldwide.
- Ask students: Do you have any ideas how we can separate the iron from the sand? *With a magnet*. *Be sure to point out that the iron is magnetic and sand is not*. *Also be sure to mention that separation by magnetism is a physical means of separation*.

Emphasize that <u>a physical property</u> of iron can be used to separate the mixture.

- Tell students that you will use a cow magnet to separate the iron filings from the sand.
- The cow magnet will already be in the jar. Pull it out of the sand, and take it around the class to show the students the iron filings on it.

Share the following information with the students:

- Cow magnets are used by farmers to protect the cow's stomachs from being punctured by small pieces of baling wire or other bits of wire that cows might eat with hay.
- Cows have four stomachs. The cow magnet is placed in the first stomach to attract bits of wire in order to keep them from entering the other three stomachs.
- Farmers or veterinarians open a cow's mouth and place the cow magnet down its throat into the first stomach.
- Cow magnets are available from farm supply stores, farmer's co-ops and science supply stores.

B. Demonstration – Making a Homogeneous Mixture

Materials

1 bag containing: 1 jar blue water, 1 jar yellow water (each about ¼ filled)

Hold the jars up so the students can see them.

Ask the students: *What color do you get when you mix blue and yellow?*

Ask: *"What will happen if you combine the 2 liquids?* Accept responses. Pour the blue liquid the yellow liquid together and show students that the mixing of the blue and yellow liquids makes a green liquid.

Ask students: Is this a homogeneous mixture? Why? *The blue and yellow liquids cannot be seen anymore.*

Did a chemical change happen? Or a physical change? (*Physical).*

II. Using Chromatography to Separate a Homogeneous Mixture (using a green Pen)

Materials: (1 set is for VSVS to use as demo)

16 16 oz. clear plastic cup with water to the mark (about 30 mL.)

Your Notes

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5 green pens
16 chromatography strips that already have the green pen trace don the horizontal line, paper is already attached to wood stick

Ask students: What colors mixed together result in green? *blue and yellow*
Show the students the green pen and tell them that the green is a *mixture* of blue and yellow inks.

Explaining: What is Chromatography?

Explain to the students that chromatography is a physical way to **separate mixtures**.
In today's lesson, paper chromatography will be used to separate water-soluble inks into their different colors, starting with a green pen and then a black pen to help solve a crime.

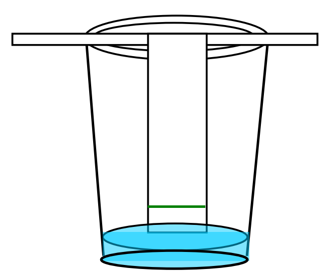
Show students:

- How the green pen was used to trace over the pencil line on the paper.
- How was the paper attached to the stick: hold the paper strip so that the top edge of the paper is even with the top edge of the wooden stick Tear a small piece of tape and tape the paper strip to the wooden stick so that the tape goes around the stick and is taped to both the front and the back of the paper strip.
- Take one of the 16 oz cups that contains 30 mL of water and gently place the stick across the 16 oz. cup so the stick and paper will not fall into the cup. The strip should hang free in the center of the cup without touching the sides.
- The bottom of the paper should be in the water, BUT make sure the **green line does not** touch the water

PASS MATERIALS OUT TO PAIRS OF STUDENTS

- Each VSVS member will help students do this experiment
- As the water starts to go up the paper strip, show the strip to the students and tell them that this **capillary action** will help separate the colors.

Explanation:
Liquids can climb up paper, string, and other substances through the process of **capillary action**. The liquid moves upward through small pores, or capillaries, that are found in paper towels, filter paper, chromatography paper, and other porous materials; this is what makes these materials absorbent. Scientists use this process to separate mixtures, including colors.



Background – Adapt to your class.
The paper is the **support** in this experiment. The **solvent** used (water in this case) has different degrees of absorption to the support. The greater the porosity of the paper, the better the capillary action or wicking, and the faster the water will climb. As the water moves up the paper strip, it dissolves the water-soluble pigments of the green pen mark. Each pigment travels at a different speed depending on its solubility in water and its absorption on the paper. The color separation is called developing a **chromatogram** (a color pattern). Chromatograms can be used to match and identify substances in biology, chemistry and forensic labs.
A simpler explanation is that the solvent carries the pigment farther if the pigment is more water soluble.

Your Notes

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III. Forensic Chromatography

Tell students that:

- Chromatography is used in crime labs to separate components of "clue" substances such as blood, ink, or other mixtures found at the scene of the crime.
- Forensic scientists or detectives can also use the process of chromatography in their work.
  - The same pen will always show an identical pattern of separation into its separate colors. This is because pens include a specific ink that has a specific mixture of pigments.
  - This illustrates how scientists can use chromatography for analysis.
- Chromatography can be used to identify the pen that was used to write a ransom note.

Read or tell the following scenario to students and tell them they will use chromatography to determine "Whodunit"!

NOTE: - You can change the scenario, BUT you cannot make it gory, have anything to do with sexual stories, or upsetting to young 5th graders.

The police (represented by Sam Suede, a hard-boiled police detective) have been called to the scene of a crime. The scene is a chemistry laboratory, and a small vial of Solution X has been stolen. A ransom note has been received, written in black ink, demanding one million dollars for the return of Solution X. Through questioning, Sam Suede learns that rumors have been spreading that Solution X may be the long-awaited cure for the common cold!

Sam discovers that there are four prime suspects who all have a motive for committing this crime. They are as follows:

- Pam Chromatogram (Pen PC)
- Mary Masonite (Pen MM)
- Patrick Street (Pen PS)
- John Fingerprint (Pen JF)

Sam has obtained a pen from each of these suspects and has a chromatogram that was made from the ransom note. Sam needs your help in matching the suspect's pen to the ransom note.

Distribute the following materials to each **pair:**

- 1 piece of chromatography paper
- 1 16 oz clear plastic cup –students already have
- 1 stick – students already have, but the green chromatogram needs to be removed.
- 1 roll of clear tape
- 1 paper towel
- 1 black pen - student pairs will need to share the black pens and tape

Each pair will follow the procedure demonstrated in Part II to obtain a chromatogram of one of the suspect's pens.

Have each of the students do the following:

- Trace the pencil line with their black pen.
- Tell each student to mark the top of the chromatography paper near the stick with the initials on their pen (PC, PS, JF, or MM) **with a pencil**.
  - Hold up a stick with a piece of chromatography paper taped to it to make sure the students know where to place the initials – **at the top near the stick**.
- Take the 16 oz cup that contains 30 mL of water and gently place the stick across it so the stick and paper will not fall into the cup. The strip should hang free in the center of the cup without touching the sides.
- Wait about five or six minutes for development of the chromatogram.

Your Notes

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After the chromatogram has developed enough so that the different colors can be identified, tell the students to:

- Lift the stick out of the cup and remove the chromatogram from the stick by holding the paper near the taped end and sliding it off the stick.
- Place the chromatogram on a sheet of paper towel.

Ask 4 students to describe the 4 different chromatograms. The results can be put on the board, or shown to the class. **<u>Emphasize that each pen has a unique chromatogram.</u>**

Distribute the 16 laminated chromatograms prepared from the guilty person's pen and ask them to compare it to their chromatogram. Identify which pen matches the results from the ransom note.

Ask students: Who is the guilty person? *PC - Pam Chromatogram*

IV. Review of chromatography

Adapt to your class:
In most of the variations of chromatography, a substance (ink dot, candy coating, leaf extract) is placed onto a support (paper strip). A solvent (water, alcohol) is then added, which moves up the support because of capillary action. As the solvent moves through the test substance, some of the test substance is dissolved in the solvent and carried up the support. Different types of substances move different distances, which depend on their differences of solubility in the solvent and their absorption on the paper. As a result, separation occurs. This is always constant for a particular support and solvent. Chromatograms of these substances are then compared with known chromatograms to identify the substances.

REVIEW QUESTIONS

1. Why does water move up the paper strip?
   <u>Answer</u>: capillary action
2. In the separation of the green ink, the blue pigment moves higher (faster) than yellow pigment. Why?
   <u>Answer</u>: The speed of movement of a component of a mixture, in this case colors, depends on its relative solubility in the solvent (water) and its relative strength of attachment (absorption) to the paper. The blue pigment is more soluble (more attracted to water than to the paper) and less absorbent (less attracted to the paper) so it moves faster up the paper strip.

<u>References</u>

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Lesson written by Dr. Melvin Joesten, Emeritus Professor, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Program Coordinator of VSVS, 1998-2018, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University
Dr. Todd Gary, former Coordinator of VSVS, Vanderbilt University

Your Notes

Chromatography Observation sheet

Name:________________________

Chromatography Part I: Separation of Green Colors

1. What did the color change to when the yellow and blue solutions were mixed?

   ____

2. What happened to the marker's green color on the chromatography paper.

   ____

3. What can you conclude about the green ink? How many dyes are used to give it its color?

   ____

4. Which color traveled faster?

   ____

Chromatography Part II: Forensics Using Black Pens

5. Draw and label your results on the "chromatography paper" below. Include the initials of the suspect's pen on the diagram.

6. Is your chromatogram the same as those from other black pens?

   ____

7. Whose pen was used to write the ransom note?

   ____

Answers Chromatography Observation sheet

Name:________________________

Chromatography Part I: Separation of Green Colors

1. What did the color change to when the yellow and blue solutions were mixed?
______green_________________________________

2. What happened to the marker's green color on the chromatography paper.
______________separated into yellow and blue_____

3. What can you conclude about the green ink? How many dyes are used to give it its color?
___2 dyes___________________________________

4. Which color traveled faster?
_____blue________________________________

Chromatography Part II: Forensics Using Black Pens

5. Draw and label your results on the "chromatography paper" below. Include the initials of the suspect's pen on the diagram.

6. Is your chromatogram the same as those from other black pens?
________not all_______________________________

7. Whose pen was used to write the ransom note?
_________PC – Pam Chromatogram_______________

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorg.vanderbilt.edu/vsvs

Polymer Chemistry

Spring 2019

Goal: To introduce the concepts of polymers and cross-linkers and to investigate their properties.
Fits TN State Science Standards 5PS1.1, 5PS1.4

VSVSer	Lesson Outline
_______	**I. Introduction - Solids, Liquids, Gases, and Polymers.** Two VSVS volunteers conduct this section while other volunteers prepare the cups and the blue and yellow slime for the demonstration. A number of activities demonstrate the differences between polymers involve the use of student volunteers. Ask the teacher to help in selecting students who are willing to link arms.
_______	**II. Tearing a Newspaper.** Students find that a newspaper tears straight in one direction and crooked in the other direction. Explain that newspaper is made from cellulose, a long-chain polymer.
_______	**III. Skewering a Plastic Bag** This demonstration illustrates both the elasticity of some polymers and the porosity of matter. Practice this one before teaching the lesson.
_______	**IV. Making Slime.** Students make slime by mixing solutions of PVA and 4% borax.
_______	**V. Determining the Properties of Slime.** Students perform a number of tests on the slime and record their observations on an observation sheet. For Observation 6 show the students the 2 cups containing the blue and yellow slime. Add one of the colored slimes to the other. By the end of the period you may be able to see green color at the interface.
_______	**VI. Review.** Review the results of the tests in part V in terms of properties of solids and liquids. Explain the classification of slime as a non-Newtonian liquid.

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. What are the three different States of Matter?
2. What is a polymer? Give some examples. What makes polymers so useful?
3. You named some different types of polymers earlier. Some of them are really strong and sturdy while others are soft and flexible. What causes these differences?
4. Why is slime so different from the things you used to make it; what kind of reaction occurred? Is slime a solid or liquid?

2. During the Lesson:
Here are some Fun Facts for the lesson

There is another non-Newtonian fluid you can make at home called "oobleck". If you mix corn starch and water, it can make an ooze that drips like a liquid but feels solid when you press it.

Polymers can be thousands, even millions, of molecules long. A polymer chain of 10,000 subunits is proportional to a half-inch thick rope that is 140 yards.

Different polymers can have very different strengths. For example, the newspaper is very easy to tear, but carbon nanotubes and graphene, other type of polymers, are some of the strongest materials in the world for their size. A more common super strong polymer is spider silk, which is, accounting for weight, stronger than steel.

The difference in strengths between polymers is partly based on the types of chains formed by them. If you change the ratio of PVA and borax you use, it can result in more or less bonds being created and more or less oozy slime.

We're made up mainly of polymers. All four of the major biological groups (nucleic acids, proteins, carbohydrates and lipids) are polymers.

Unpacking the Kit – things you will need for each section

For Part I. Introduction

1 Bag containing: Plastic water bottle with cap, sandwich bag, polyester sock (or other polymer blend)

Management Note: Two VSVS volunteers should conduct the Introduction section of this lesson while the other one or two volunteers prepare the cups for the slime and then make the blue and yellow colored slime for the Demonstration in part VI.

Preparation for Experiment:

- Count the students and prepare enough cups so each student will have one.
- Use the small marked cup to measure 10 mL borax and pour this amount into a ziploc bag inside a 10 oz cup.
- Measure 50 mL of 4% polyvinyl alcohol into enough 3.5 oz cups so each student will have one (fill to line on cups which is 50 mL)

Making Blue and Yellow Slime

- Use the materials in the bag containing: 2 containers PVA (containing 50mL each), 2 small bottles borax – 1 with blue food coloring added, and 1 with yellow food coloring added, 2 clear 10 oz cups, 2 popsicle sticks
- Pour the blue borax into one of the 10oz cups and add the PVA. Stir with a popsicle stick until it is thick.
- Repeat with the yellow borax and PVA in the second cup.
- Set aside the 2 cups until later.

For Part II. Tearing a Newspaper:

32 ¼ sheets of newspaper

For Part III. Skewering a Plastic Bag

1 plastic bag containing:3 plastic bags, 2 skewers (1 extra), 1 small container of glycerin, 1 paper towel, 1pie plate

For Part IV. Making Slime

32 10 oz. cups (inserted with ziploc bags that contain 10 mL of 4% borax)
32 3.5 oz plastic cups (with 50 mL of PVA)
32 2oz cups
32 small plates
1 Borax box front

Your Notes:

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34 Instruction Sheets
32 Observation Sheets

Note: Cups for this experiment should have been prepared for the students at the beginning of the lesson while two VSVS volunteers conducted the Introduction Section of the lesson.

For Part V. Determining the Properties of Slime.

I. Introduction

Learning Goals:
- **Students compare and contrast the molecular arrangement and properties of different States of Matter, including solids, liquids, gasses, and non-Newtonian liquids.**
- **Students define polymers as a chain of molecules linked by chemical bonds.**
- **Students model how changing the composition of a substance can change its properties**

Materials:
1 Bag containing:
Plastic water bottle with cap
sandwich bag
polyester sock (or other polymer blend)

- A VSVS member should put the following vocabulary words on the board:
  solid, liquid, gas, polymer, non-Newtonian liquid, cross-linking
- Ask students: What is the difference between solids, liquids, and gases?
- Make a chart on the board to compare properties of solids, liquids and gases.
- Have a students brainstorm about properties of each. Write their responses on the board under the appropriate headings.
- Some answers can be:

A Solid	A Liquid	A Gas
has definite shape	has no definite shape (flows and takes the shape of a container)	has no definite shape (fills the container)
can break into pieces	does not break into pieces	does not break into pieces
takes up a definite space	takes up a definite space	Does not take up a definite space
particles are packed tightly together and move slowly	particles are not packed very tightly and move faster than those in a solid	particles have the greatest amount of movement (free to move anywhere in the container).

Tell the students that they will focus on solids and liquids and their characteristics.

Modeling Solids, Liquids and Gases:
Use 8 student volunteers to demonstrate the properties of solids, liquids, and gases. **Ask the teacher to**

Your Notes:

help in selecting students who are willing to hold arms.

Solids:
- Ask the 8 volunteers to come to the front and stand in a close cluster (not in two lines).
- Instruct the students to look at a spot on the floor and take baby steps around that spot in a side to side or forward and backward manner.
- They should also vibrate their bodies to simulate molecular movement.
- Explain to the students that this is a model of the molecules in a solid. The movement is limited but is constant.
- Molecules in solids do not travel far but they are constantly vibrating.

Note: In the next activity, students will be moving around in the room. Encourage them to move carefully. If they bump into objects or other "molecules" they should do this gently.

Liquids:
- Now have the same students move an arm's length away from the other students.
- They should continue to vibrate while they move around a small section of the room (whichever section you choose to designate).
- Explain that this is a model of the molecules in a liquid; the molecules move more freely than the molecules in a solid.

Gases:
- Tell the same students to continue to vibrate and allow them to move freely throughout the room.
- These students now represent the molecules of a gas.
- The molecules in a gas can fill up the entire space. Actually, to be more accurate, the students would have to be able to fly around the room to simulate the molecules in a gas.

Note: Have the volunteers return to the front of the room and freeze in place while you share the following information with the students.

Modeling Polymers:

Now that we know how molecules move in the three states of matter, we are going to investigate a special class of large molecules that are made by forming chemical bonds between a large number of small molecules. The product that we are going to investigate is called a **polymer**.
- Polymers occur as natural products (cotton, wool, hair, DNA) or are manufactured (polyethylene, nylon, plexiglass, styrofoam).
- Molecules in any state (solid, liquid, gas) can join together to create polymers.

Using the volunteers to demonstrate this process:
- When the molecules are separate, each one is called a **monomer** because "**mono**" means **one**.
- Ask the molecules (students) to lock arms and form a chain.
- Tell students: When we join the monomers, we have created a **polymer**.
- Ask students: Since "mono" means one, what do you think "poly" must mean? (*Many*)
- Joining monomers to form polymers is a **chemical reaction** because a new substance is created.
- Break the human "polymer" chain into two smaller chains of four students each.
- Ask the two chains to walk across the room.
- Ask them if it is easier to move as an individual or as a chain.
- Then have the groups stand facing each other.
- Ask for two more volunteers. Have each new volunteer stand between the two chains and grasp the upper arm of a molecule (student) from each of the two different chains. These new students are the cross-linkers that join the two chains. (See picture below.)
- Ask the entire group to walk across the room.

Your Notes:

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- Ask if the cross-linking made movement more difficult. *Groups should conclude that it is more difficult to move with the cross-linkers*.
- Thank the student volunteers and ask them to return to their seats.

2 polymer chains joined by cross-linkers:

Examples of Polymers:

- Show students the four polymer samples: **sandwich bag, plastic water bottle and cap, sock**.
- Explain that these are examples of things made out of polymers.
- They differ because of the way in which the molecules are joined.
- Cross-linking is one way to join polymers that will be explored in the following activities.
- There are thousands of polymers used in a variety of everyday products.

II. Tearing a Newspaper

Learning Goals: Students define polymers as a chain of molecules linked by chemical bonds

- Give each student one of the small pieces of newspaper.
- Tell them to tear it one way and then the other way. (They will find that it tears straight in one direction and crooked when they tear the other way.)
- Explain that newspaper is made from cellulose, a long-chain polymer of (β-glucose) monomers.
- When you tear one way, you are tearing between chains (parallel to chains), and you get a cleaner tear. Tearing the other way doesn't give a straight tear because you are tearing across the chains.
- The cellulose in newspaper is an example of a polymer that exists in nature.
- Other naturally occurring polymers that students would be familiar with are proteins, DNA, RNA, starch.

III. Skewering A Plastic Bag

Materials

1 plastic bag
1 skewer
1 small container of glycerin
1 paper towel
1 pie pan

1. Take one of the plastic ziploc bags and fill it about one-fourth full with water.
2. Take the skewer and dip the sharp end in the glycerin (small vial) to lubricate the end.
3. One VSVS member should hold the ziploc bag on an angle over an aluminum pie pan while another VSVS member uses a gentle twisting motion to push the skewer through the part of the ziplock bag where the water is located.
4. Show the class that the ziploc bag is not leaking water even though the skewer has been pushed all the way through the bag. Tell them they can try this at home with a pencil.

Your Notes:

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5. Carefully remove the skewer while the bag is still over the pie plate (it will leak), or over a sink if the classroom has one. Put the skewer back in the kit box and discard the plastic bag.

For VSVS Information Only: The sandwich bag is made up of branched polymer chains, the water bottle is composed of densely packed linear polymer chains, and the cap is composed of cross-linked polymer chains.

EXPLANATION: Plastics are made from long chain polymers. The skewer goes through without breaking the polymer strands of the plastic, and there is a tight fit around the skewer so the bag doesn't leak water. When the skewer is removed, water will leak out of the holes made by the skewer.

IV. Making Slime

Learning Goals: Students model how changing the composition of a substance can change its properties

Materials

32	10 oz. cups (inserted with ziploc bags that contain 10 mL of 4% borax)
32	3.5 oz plastic cups (with 50 mL of PVA)
32	2oz cups
32	small plates
1	Borax box front
34	Instruction Sheets
32	Observation Sheets

Note: Cups for this experiment should have been prepared for the students at the beginning of the lesson while two VSVS volunteers conducted the Introduction Section of the lesson.

- Share the following background information on slime with the students:
  - Slime is a polymer compound that exhibits properties of both a solid and a liquid.
  - Scientists call this a **non-Newtonian liquid**.
  - The reaction between PVA and borax happens quite quickly, although the slime will change slightly as it is kneaded.
  - It starts off slightly moist and quickly stabilizes into an unusual combination, with some of the characteristics of a liquid and some of a solid.
- Give the following to each student:
  - 1 cup with 50 mL of 4% PVA
  - 1 (10-12 oz) cup containing a Ziploc bag filled with 10 mL 4% borax solution
  - 1 small plate
  - 1 2oz cup
  - 1 Instruction Sheet
  - 1 Observation Sheet
- Tell students to follow the directions on the instruction sheet. (Same as those given below.)

  You will still need to still guide them through the procedures, making sure they understand the instructions.

- Have students place the cup of PVA and cup of borax plate on the plate.
- Ask students to describe the two liquids. *The PVA solution is thicker than the borax solution*.
  - **Polyvinyl alcohol** is a polymer that has a chain structure.

Your Notes:

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    - These chains are able to slip by each other like the noodles of freshly cooked spaghetti. The noodles are long enough to make the solutions thick and gooey.
    - But when the borax is added, things change!
- Show the students the Borax box front cutout and explain that:
    - Borax is a solid chemical used in detergents.
    - Borax was added to water to make the borax solution that is in the small cup on their desks. Green food coloring was also added.
    - Borax is the cross-linker in this activity. (Relate the human cross-linker from the previous demonstration to the borax used in the PVA.) The borax links the long chains of PVA together, which combines with the PVA to make Slime.
- Have students pour the PVA solution into the borax solution in the Ziploc bag.
- Show the students how to take the sandwich bag out, close the top, hold the bag with one hand and knead the solutions inside until Slime, a thick gel is formed.
- Ask the students to describe the slime. (The slime forms a thick gel within 1-2 minutes squeezing the outside of the bag with their hands.)
- Explain that slime is a thick gel because the borax is the "cross-linker" between polyvinyl alcohol chains. By mixing the solutions, the students have made a cross-linked polymer.
- Ask students if Slime is the result of a physical or a chemical change and explain why.
    - Emphasize that Slime is evidence of a **chemical change**, because the PVA and the borax react to form a new substance that is a polymer compound.
    - The borax acts as the cross-linker to produce a substance that has different properties from both the PVA and the borax.

V. Determining the Properties of Slime

Learning Goals: Students compare and contrast the molecular arrangement and properties of different types of matter, including solids, liquids, gasses, and non-Newtonian liquids

Note: Do the following demonstration before the students test the properties of their slime.

- Show the students the 2 cups containing the blue and yellow slime.
- Ask the students what happens when you add blue water to yellow water. *The solution will turn green*.
- Ask the students what will happen when you stack a blue solid on top of a yellow solid. *Nothing will change*.
- Tell the students that they can test if the slime is more like a solid or liquid by observing what happens to the two different colored slimes.
- Add one of the colored slimes to the other.
- Leave the cup set on the front desk in the classroom. By the end of the period you may see green color at the junction of the two slime layers. Leave the cup with the class and tell them to look at it the next day. After 24 hours, all of the slime will be green.
- Tell the students that this illustrates a liquid property of slime since the blue and yellow mix together.
- Have the students perform the following tests by following the instructions on the instruction sheet. Tell them to refer back to the table you put on the board that lists properties of solids and liquids and write their responses (liquid or solid) on their observation sheet.
- Circulate among the students to check their responses without interrupting the flow of the experiment.

Your Notes:

Note: Do as many of these as time permits; make sure you leave enough time at the end of the lesson for a review.

- Students should take the slime out of the Ziploc bag and work it around with their hands until it is not sticky and then form it into a ball.
- Students don't have to get all of the slime. Some will stick to the side.
- Break off half of the slime, squeeze it into a ball, and roll it gently between the palms of the hands to smooth the ball. Place it in the 2-oz cup and set aside until Observation 3.

Observation 1

- Take the other half of slime and roll it into a cylindrical shape (make a snake 2-3 inches long).
- Hold the cylinder at both ends and **slowly** pull it apart.
- Ask students: Is this more like a liquid or a solid*? It droops in the middle; it is more like a property of a liquid*.

Observation 2

- Roll the slime into a cylindrical shape again and pull it apart quickly.
- Ask students: Is this more like a liquid or a solid? *The slime breaks; this is more like a property of a solid*.

Observation 3

- Have students look at the ball of slime they placed in the 2oz cup.
- What happened? *The ball has flattened on the bottom and taken the shape of the cup*.
- Ask students: Does this change demonstrate a property of a liquid or a solid and why? *liquid - because it flows and takes the shape of its container*.

Observation 4

- Roll the slime into a ball and drop it on a clean desktop.
- Ask students: Is this more like a liquid or a solid? (It bounces, but it will shatter if you throw it too hard.) *Bouncing and shattering are more like properties of a solid*.

Note: VSVS team members may want to do the shattering part of this observation if the classroom is carpeted, or the class is unruly.

Observation 5

- Roll the slime into a ball and put it inside the ziploc bag. Force all the air out of the bag, zip it and place it on the desktop.
- Use the bottom of your fist and hit the ball in the bag.
- Ask students: Is this more like a liquid or a solid? *The slime breaks into pieces, which is more like the property of a solid*.

Observation 6: Demonstration

- Show the students the clear cup with the blue and yellow slime layers.
- Is there any green color at the interface?
- If so, explain that the green is there because the blue and yellow layers have mixed (reminding them that mixing blue and yellow colors produces green).
- Ask students: Is this a property of a liquid or a solid? *Liquid*

Have students put their slime into the ziploc bag and seal it so they can take it home. Give them the following information about Slime:

- Do not put slime in the sink. It can plug up the drain.
- Slime will get stuck to clothes or carpet. If this happens, use vinegar to help remove it.
- The slime will keep about two weeks. When mold starts forming, discard the slime.

Your Notes:

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- Do not eat the slime and do not let little brothers or little sisters play with it (as they may eat it).
- Tell students to try to make impressions with coins or small objects at home. A solid will hold an imprint.
- Tell them to go to the VSVS web site (given on their observation sheet) for other ways to make polymers.
- Tell students that their observation sheet has instructions on how to care for their slime.

Clean-Up: Roll up the papers and throw them away after this activity. Put all used cups and plates in the trash bag and place it in the kit. **We re-use plastic cups and plates.**

VI. Review

Go over the observation sheet responses with students (see answer sheet) and ask:

- When does the slime act like a solid? Liquid?
- How do you know if a chemical or physical change occurs when the slime is made?

Tell students they might like to read Bartholomew and the Oobleck by Dr. Seuss.

References: 1. Journal Editorial Staff, J. Chem. Educ., 1998, 75, 1432A
2. Kids & Chemistry: Hands on Activities and Demonstrations, American Chemical Society.
3. *Fun with Chemistry*, Vol. 2; Sarquis, M; Sarquis, J., Eds.;, Publ. 93-001; Institute for Chemical Education, University of Wisconsin: Madison, 1991; pp. 67-76, 81-88, 95-99.

Lesson written by: Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University
Dr. Joe Lopez, Vanderbilt Center for Science Outreach

Your Notes:

DETERMINING THE PROPERTIES OF SLIME
Observation Sheet

Name ____

Vocabulary words: solid, liquid, gas, polymer, non-Newtonian liquid, cross-linking

Follow the instruction sheet to perform observations on slime. After each observation, determine if it is more like a solid or liquid by putting an X in the correct column, and then write in the reason why (choose from the list below.)

Solid:
has definite shape
can bounce or break into pieces
can be stretched

Liquid:
flows, can take the shape of the container
does not break into pieces

Observation #	Solid	Liquid	Why?
1-pull apart slowly			
2-pull apart quickly			
3-put into a cup			
4-drop it			
5-hit it			
6-2 colors added together			

What is the name given to a substance that has solid and liquid properties?

____

Instructions for handling slime at home:

- Do not put slime in the sink. It can plug up the drain.
- Slime will get stuck to clothes or carpet. If this happens, use vinegar to help remove it.
- The slime will keep about two weeks. When mold starts forming, discard the slime.
- Do not eat the slime and do not let little brothers or little sisters play with it (as they may eat it).
- Try to make impressions in your slime with coins or small objects at home. A solid will hold an imprint.
- Go to the VSVS web site (http://studentorg.vanderbilt.edu/vsvs) for other ways to make polymers.

DETERMINING THE PROPERTIES OF SLIME
Observation Sheet - Answers

Name ____

Vocabulary words: solid, liquid, gas, polymer, non-Newtonian liquid, cross-linking

Follow the instruction sheet to perform observations on Slime. After each observation, determine if it is more like a solid or liquid by putting an X in the correct column, and then write in the reason why. (choose from the list below.)

Solid:
has definite shape
can bounce or break into pieces
can be stretched

Liquid:
flows, can take the shape of the container
does not break into pieces

Observation #	Solid	Liquid	Why?
1-pull apart slowly		X	Flows
2-pull apart quickly	X		Breaks
3-put into a cup		X	Flows and takes shape of its container
4-drop it	X		Bounces
5-hit it	X		Breaks
6-2 colors stacked together		X	Two colors flow together

What is the name given to a substance that has solid and liquid properties?

________________**Non-Newtonian liquid**____________________

Check out the Vanderbilt web site for more information on polymers at:
http://studentorg.vanderbilt.edu/vsvs

IVVANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorg.vanderbilt.edu/vsvs

Rates of Chemical Reactions

Spring 2019

Goal: To understand factors which affect the rates of chemical reactions - temperature, surface area (particle size), and concentration.
Fits TN standards: 5.PS1.3, 5.PS1.4

VSVSer 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 .

_______ **IIIa. 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.

_______ **IIIb. 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.

_______ **IV. 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.

________ **V. 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.
2. What are some visual indications that a chemical reaction has occurred?

2. Use these fun facts during the lesson:

- The name of a famous James Bond movie, “Diamonds are Forever” doesn’t quite hold up in reality. Diamond is a form of carbon that exists only at very high pressures well below the Earth’s surface; at the Earth’s surface, carbon’s more stable form is the graphite you see in your pencils. However, the rate of the reaction from diamond to graphite is very slow, so the diamonds in your jewelry aren’t going anywhere anytime soon.
- An example of how temperature affects reaction rates is that cookies bake faster at higher temperatures.

- 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.

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

One VSVS team member should write the following vocabulary words on the board while another member starts discussing the background information:

rate, chemical reaction, surface area, concentration

Students should have their pencils ready

For Part I. (At end of Introduction)

22 Instruction Sheets (in sheet protectors) (5 for VSVS team)
32 Observation Sheets (one per student)

For Part II The Effect of Temperature on the Rate of a Reaction

1 container of ice
10 3.5 oz cups marked for 50 mL containing ice
10 3.5 oz cups marked for 50 mL (empty)
20 10 oz. clear plastic cups
10 200 mL bottles of water
10 plates
10 packets of 2 effervescent tablets
10 pairs of scissors

For Part IIIa. The Effect of Surface Area: Demonstration

1 box of matches	1 lighter	1 vial of lycopodium "dust" powder
1 pipette (jumbo size)	1 tea light candle	1 aluminum pan
1 sugar cube	1 small plate	

For Part IIIb. The Effect of Surface Area on the Rate of a Reaction Experiment

20 10 oz dry cups, 10 packets of 2 effervescent tablets, 10 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 IV. Effect of Concentration on the Rate of a Reaction

Materials for demonstration
1 plastic bag containing:
- 2 100 mL graduated cylinders (clear),
- 1 jar Koolaid powder,
- 1 200 mL bottle of water
- 1 piece of copy paper,
- 1 mini scoop,

Materials for the experiment:
10 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 1spoon

Your Notes:

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I. Introduction

Learning Goals: • **Students understand what is meant by "the rate of a reaction".** • **In Parts II-V, students will understand the different factors that affect the rate of a reaction and why.**

Why is the science in this lesson important

Knowing and controlling the rate of reactions is important in living cells and industry.

In the body chemical reactions must take place at the correct rate to supply your cells with exactly what they need when they need it.

In industry, the products of chemical reactons make money so it is important to be able to speed up the rate and make them as cheaply as possible

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.

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.

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. This is a **chemical reaction** as evidenced by the production of a gas.
- Write on the board: citric acid + sodium bicarbonate releases carbon dioxide
- The rate of the reaction of Alka Seltzer in water can be measured by measuring the rate at which carbon dioxide is given off

II The Effect of Temperature on the Rate of a Reaction

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

Introduction

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

Your Notes:

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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.
- 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, other VSVS volunteers 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.**

Procedure:
Give each GROUP of THREE the following:

1	plate	1	packet of 2 effervescent tablets
1	200 mL bottle of water	1	3.5 oz cup filled with ice to the 50 mL line
2	10 oz. cups	1	3.5 oz cup marked with a 50 mL line (empty)
1	pair of scissors	3	observation sheets

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

Your Notes:

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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.

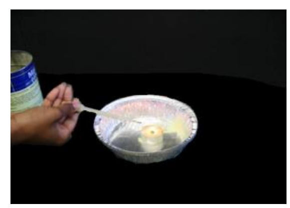
Ask students: Is the total amount of carbon dioxide given off in both the slow and fast reaction the same if you wait until the reaction is over?
Yes. It is important for students to realize that since we started with the same amount of substance, as represented by the whole tablet in both cases, we 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.

IIIa. 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.

Material's – 1 sugar cube, 1 plate

- 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 the sugar cube. Ask them to describe what the surface area of it. Point to the different faces
- Now break the cube into sugar crystals (on a plate) and ask them to describe the surface area.
  - Is it larger than the cube? (yes)



Ask them to predict which would dissolve faster in water – the whole cube or the smashed cube?
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

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

- 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 pipetteso the tip is facing down, about 6 inches above the flame and squeeze the pipette bulb to release the lycopodium powder into the flame.
- There will be a flash of fire.

Your Notes:

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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.)

This demonstration 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.

IIIb. 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.
- 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

Your Notes:

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 ALL 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.

IV. Effect of Concentration on the Rate of a Reaction

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 (ie four times more concentrated) as the solution with one scoop.*
- Tell students that the weak and stronger vinegar solutions were

Your Notes:

prepared in a similar way.

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:
- 1 bottle with 50 mL of strong vinegar (20%),
- 1 bottle with 50 mL of weaker vinegar (5%)
- 1 container of baking soda, 1 spoon

(They should already have a plate and bottle of water per team)

- 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.

V. 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

Your Notes:

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the reaction.

2. Ask students: What effect did surface area have on the rate of reactions? The temperature of the water was constant, and the surface area was varied by using a whole tablet and a crushed tablet.

   In this case, the crushed tablet reacted faster because of the higher surface area of the particles as compared to the whole tablet.

3. Ask students: What effect did concentration have on the rate of reactions?

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.**
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, Program Coordinator 1998-2018, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University

Reference: Journal Editorial Staff, *J. Chem. Educ*. 1998, 75, p. 1120A

Your Notes:

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ANSWER SHEET
Rates of Reaction

Name ____

Vocabulary words: rate, concentration, chemical reaction, 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 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.**

IV**. Effect of Concentration – weak vs strong vinegar**

Which was faster? **Strong vinegar**.

How can you tell? **Bubbles come off faster**

OBSERVATION SHEET – Rates of Reaction

Name ______________________________
Vocabulary words: rate, concentration, chemical reaction, surface area

II. Effect of Temperature – Ice water vs. room temperature water Which was faster?
Circle the correct answer: **room temperature water** **ice water tempeature**

How can you tell? ____

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

____

III. 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?

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2. Which tablet reacts faster? Circle the correct answer: – **crushed** **whole**

Why? ____

IV. Effect of Concentration –weak vs. strong vinegar
Which was faster? Circle the correct answer: **weak vinegar** **strong vinegar**

How can you tell?____