5^{th} Grade

Spring 2022 Lesson Plans

Vanderbilt Student Volunteers for Science

https://studentorg.vanderbilt.edu/vsvs/

VOLUNTEER INFORMATION

Team Member Contact Information

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:	Molly Friedman	molly.h.friedman@vanderbilt.edu
	Alex Ruemmler	alex.k.ruemmler@vanderbilt.edu
Secretaries:	Doah Shin	doah.e.shin@vanderbilt.edu
	Neeraj Namburu	neeraj.s.namburu@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: https://studentorg.vanderbilt.edu/vsvs/lessons/

- 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 start the lesson without them.
- 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 used for lessons 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.

Just relax and have fun!

February						
SUN	MON	TUES	WED	THU	FRI	SAT
	31 Applications Close	1	2	3	4	5
6	7	8	9 Team Leader Training 4-5 PM	10	11 Next Steps Lesson #1 2-3 PM	12
13 Team Leader Training 4-5 PM	14 5th/7th Grade Training Sessions	15 5th/7th Grade Training Sessions	16 5th/7th Grade Training Sessions	17 5th/7th Grade Training Sessions	18	19
20	21 6th/8th Grade Training Sessions	22 6th/8th Grade Training Sessions	23 6th/8th Grade Training Sessions	24 6th/8th Grade Training Sessions	25	26
27	28 First week of lessons					

March						
SUN	MON	TUES	WED	THU	FRI	SAT
	28 First week of lessons	1 First week of lessons	2 First week of lessons	3 First week of lessons	4	5
6	7 **No Lessons** VU Spring Break	8 **No Lessons** VU Spring Break	9 **No Lessons** VU Spring Break	10 **No Lessons** VU Spring Break	11	12
13	14 **No Lessons** MNPS Spring Break	15 **No Lessons** MNPS Spring Break	16 **No Lessons** MNPS Spring Break	17 **No Lessons** MNPS Spring Break	18 Next Steps Lesson #2 2-3 PM	19
20	21 Second week of lessons	22 Second week of lessons	23 Second week of lessons	24 Second week of lessons	25	26
27	28	29	30	31		

April						
SUN	MON	TUES	WED	THU	FRI	SAT
				31	1	2
3	4 Third week of lessons	5 Third week of lessons	6 Third week of lessons	7 Third week of lessons	8 Next Steps Lesson #3 2-3 PM	9
10	11 Fourth week of lessons	12 Fourth week of lessons	13 Fourth week of lessons	14 Fourth week of lessons	15	16
17	18 Lesson make-up week 1	19 Lesson make-up week 1	20 Lesson make-up week 1	21 Lesson make-up week 1	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?

Volunteer FAQ

➔ What is VSVS?

VSVS stands for Vanderbilt Student Volunteers for Science. Members of this organization volunteer to teach hands-on science lessons to 5th-8th grade classrooms in the Metro Nashville School District.

➔ How often are lessons?

Each team teaches 1 lesson per week for 4 consecutive weeks throughout a semester.

➔ What is the time commitment?

Relatively low! Depending on your position, you'll attend between 1-3 training sessions at the beginning of the semester, and each of the 4 lessons take about 1.5 hours (30 minutes to run through each lesson beforehand and 1 hour to teach it).

➔ Who will I be teaching with?

All volunteers are put into groups of up to 3 (based on availability) and assigned to a classroom.
If you have friends that you'd like to be partnered with, be sure to have one group member fill out a separate Partner Application so you can be appropriately matched!

➔ Where will I be teaching?

Your team will be teaching your students over some virtual platform from the same room. VSVS will reserve a room where your team can meet. Social distancing rules and sanitation protocols will be enforced.

➔ What are the lesson dates?

At the beginning of each semester, we send out a group assignment email that contains all of the relevant information for your group. It will have your teachers name and contact information, as well as the names and contact for all of your group members, and the date/time of your lessons.

➔ What if I need to quit VSVS?

If you can no longer fulfill your commitment to VSVS, please reply to one of the emails we've sent you ASAP and let us know so that we can adjust accordingly.

➔ Can graduate students participate in VSVS?

Yes -- you can either join as a regular volunteer and be assigned to a team and classroom OR you can serve as a floating volunteer (that is, if your schedule is very irregular but you know that you'll be available for at least a few of our weeks!). Just note which option you'd like in your application!

For additional questions, feel free to contact the VSVS Educational Coordinator at paige.ellenberger@vanderbilt.edu.

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 GREENWOODAVE **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

Why is Mars Red?

Mini Lesson
Spring 2022

Goals: In this lesson, you will discuss the differences in iron and iron oxide and how these relate to the surface of Mars.
Introduces/Reinforces TASS: 5.PS1.4 Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change in properties.

VSVSer Lesson Outline
_____ **I. Introduction**
a. What are the general characteristics of Mars?
b. Observations of the five photos and discuss NASA's goals on Mars
c. Setting up cotton ball cups with test substances. (*activity stations to be set up by VSVSers).*
_____ **II. Activity**
a. Add Hydrogen Peroxide and Salt to the test substances
_____ **III. Discussion/Review**
a. Explanation of Iron vs. Iron Oxide
b. Tie back to how the reaction can explain why Mars is red.

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

1. In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.
Lesson Quiz
1) What are the four main goals for NASA on Mars? *Answer in Intro, section b*
2) What is expected to happen when hydrogen peroxide and salt is added to the test substances? *Answer in Section II.*
3) What are the differences between iron and iron oxide? *Answer in Section III.*

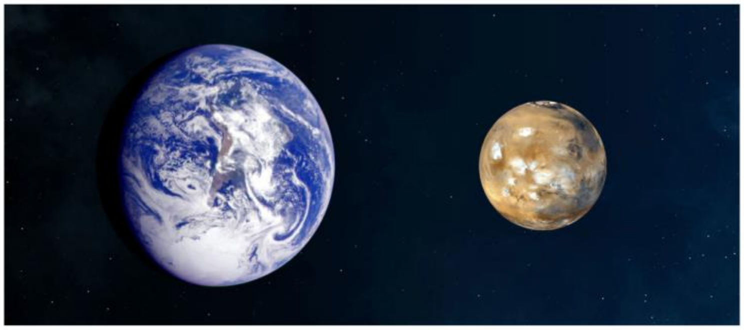
Unpacking the Kit – What you will need for each section:

Materials:

- 2 laminated photos of Mars (one of each view)
- 1 laminated photo of the Curiosity Rover's drilling
- 1 laminated photo of the Curiosity Mars Rover
- 1 laminated photo of Bagnold Dunes (taken by the Curiosity Mars Rover in 2015)
- 1 laminated Mars Exploration Timeline
- 1 laminated Mars vs Earth table
- 1 1-oz bottle zinc filings (half full is fine)
- 1 1-oz bottle wood shavings (half full is fine)
- 1 1-oz bottle iron filings (half full is fine)

- 1 1-oz bottle activated charcoal pellets (half full is fine)
- 4 mini scoops
- 4 taster spoons
- 1 1-oz bottle salt (half full is fine)
- 1 30-mL dropper bottle hydrogen peroxide (half full is fine)
- 1 periodic table in a page protector
- 1 iron element model (a bag containing only red balls)
- 1 oxygen element model (a bag containing only blue balls)
- 1 iron compound model (a bag containing red and blue balls linked together)
- 1 1-oz sealed bottle iron metal
- 1 1-oz sealed bottle iron oxide (labeled Fe_2O_3)
- 1 white Teflon magnet
- 4 1-oz cups
- 4 cotton balls
- 1 wood block
- 1 iron block
- 1 zinc chunk
- 1 charcoal brick

I. Introduction



	EARTH	MARS
Average Distance from Sun	93 million miles	142 million miles
Average Speed in Orbiting Sun	18.5 miles per second	14.5 miles per second
Diameter	7,926 miles	4,220 miles
Tilt of Axis	23.5 degrees	25 degrees
Length of Year	365.25 Days	687 Earth Days
Length of Day	23 hours 56 minutes	24 hours 37 minutes
Gravity	2.66 times that of Mars	0.375 that of Earth
Temperature	Average 57 degrees F	Average -81 degrees F
Atmosphere	nitrogen, oxygen, argon, others	mostly carbon dioxide, some water vapor
Number of Moons	1	2

I a.

Start with some general information about Mars. Tells students that Mars is the 4th planet from the sun (the planet right after Earth!) and that Mars has two moons, named Deimos and Phobos. Use the chart below (also provided as a laminated material) to compare Mars to Earth.

Show students the 5 different Mars photos. Explain the two full planet photos are from two different Mars missions, the Bagnold Dunes is a photo of "mountains" on the planet (taken by the Curiosity), the photo of Curiosity is a photo of a rover on Mars (ask: "do you know what a rover is?" *an unmanned vehicle that collects photos and other information)*, and the photo of the drilling is from where the Curiosity drilled into the planet to collect "dirt."

Ask students what things they notice from the photos. *Students should notice above all that Mars is red! But they may have other things as well. Accept all reasonable answers.*

I b.

The US space agency, NASA, has four main goals for Mars missions (as of December 2019).

1. Determine if Mars ever supported life.
2. Understand the processes and history of climate on Mars.
3. Understand the origin and evolution of Mars as a geological system.

4. Prepare for human exploration!

There are 8 active missions on Mars currently. 5 are NASA's. (Refer back to the Curiosity Mars Rover photos to explain that the US and many other countries and sending missions to learn about Mars.) Use the Mars Exploration Timeline lamination for more information. (If you'd like to tell them what some of the missions do with this, feel free. But you should focus on the fact that the US and other countries have been sending missions to Mars for a long time! Show them the poster to demonstrate this.)

1. InSight (NASA – a lander launched in 2018)
2. ExoMars Trace Gas Orbiter (European Space Agency, ESA)
3. MAVEN (NASA)
4. Mars Orbiter Mission (Indian Space Research Organization, ISRO – launched 2013)
5. Curiosity (NASA)
6. Mars Reconnaissance Orbiter (NASA)
7. Mars Express (ESA)
8. Mars Odyssey (NASA)

Ask "The surface of Mars is very red, but why? Why is the soil not brown like on Earth?" *Mars is red because something in the soil reacted with oxygen (we think from water that was present on the planet in the past!).*

I c.

Use several common elements/compounds to see which one reacts with oxygen and looks most similar in color to the photos of Mars we showed earlier (don't tell students that rusting is what we're looking for just yet!).

- Tell students that we can speed up the reaction that takes place on Mars by using salt and hydrogen peroxide (which has *lots* of oxygen in it!) and that we're going to be testing several materials to see which one is on the surface of Mars.
- Show students the cubes of zinc, wood, iron, and the brick of charcoal. Tell them that these are the materials we'll be testing, but since this reaction would take a <u>long</u> time in a quantity so large we'll be using the shavings/filings/pellets.
- "Fluff" the cotton balls so they are less spherical (so your materials don't fall into the bottom of the cup!) and place a cotton ball in each of the four 1 oz cups. Scoop a small amount of each material (zinc filings, wood shavings, iron filings, and charcoal pellets) into each cup, 1 material per cup using a clean spoon for each.

II. Activity

- Put a little salt and a squirt of hydrogen peroxide on top of each material in the cups.
- Ask students to predict which one will have the proper reaction to the increased presence of oxygen and turn red (answers will vary).
- Expected outcome – Iron will rust and produce a reddish/orange color on the cotton ball. That means that there is a lot of *iron* in the soil that is rusting and becoming **iron oxide!**
- While waiting for the reaction to take place, engage participants in discussion about which material they think will react with the oxygen and turn red like the surface of Mars while showing each one to the camera along with one of the photos of Mars for comparison.

III. Discussion/Review

Elements and Compounds – help student explore the difference between iron and iron oxide.

- Show students the periodic table in the page protector. 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).
        - Emphasize that simply tossing the iron and oxygen molecules (blue and red balls) into the same bag doesn't mean they have iron oxide. The bonds between each molecule are important!

- Allow students to use the balls to create their own iron oxide compounds if time permits.

III a.

Demonstration – Differences between Iron & Iron Oxide

- Show students the 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, and 1 white Teflon magnet. 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 (from the period table, discussed earlier), 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)*
    - o 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.
    - o 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.
- Use the magnet on each vial to show which are magnetic and which aren't.
- 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*
- 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.*
- Emphasize that the physical properties of elemental iron and iron compounds are not the same.

III b.
Review. Recap the differences between elements and compounds (iron vs iron oxide), what makes Mars red, and why.

IV. Clean-up
Tightly cap all containers and return them to the kit. Return the kit to the metal shelves in SC 5233.

Original lesson written by 2018-current VSVS Educational Coordinator, Paige Ellenberger.
Edits made by VSVS board members Robert A'Hearn, Sean Collins, Kevin Sun, Serena Pao, Aakash Basu, & Omar Amir.
Some portions adapted from Properties of Iron lesson written by 1998-2018 VSVS Educational Coordinator, Pat Tellinghuisen.

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Comets

Spring 2022

Goal: To teach students the importance and composition of comets.
Introduces/reinforces TASS: 5.ESS1.3 Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.

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.

VSVSer	Lesson Outline
_______	**I. What are Comets?**
_______	**II. Where are Comets Found?**
_______	**III. What is a Comet Made Of?**
_______	**IV. Making a Comet**
	Students simulate a comet by combining dry ice, water, charcoal, ammonia and dirt.
_______	**V. Observing the "Comet"**
	Students watch their comet as it gives off gas. It can be broken with a hammer to observe the inner part of the comet.
_______	**VI. Observing the Tail**
	Dry ice is used to simulate the tail of the comet.
_______	**VII. Comparing Comets with Asteroids and Meteorites**
_______	**VIII. Clean-Up**

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.

Comets Lesson Quiz

1. Are most comets formed before or after a solar system? *After*
2. Do most comets stay close to the Sun? *No, their orbit is very large and elliptical*
3. Are all comets the same size? *No*
4. Do comets orbit the Sun forever? *No, they eventually leave behind a remnant of rock and dust*
5. Which way does the tail of the comet face in terms of the direction in which the comet is moving? *Answer in Section 6*

Here are some Fun Facts:

- Comets do not always have tails. The tails only appear when they comet gets near a star, such as the Sun, which heats up the comets and vaporizes the materials in the nucleus to create a tail.
- Comets are different from asteroids. While asteroids are formed within the inner solar system (inside the orbit of Jupiter), comets are formed in the outer solar system.
- Even though there is usually only one comet each year we can see with the naked eye, there are potentially up to 1 trillion comets in the solar system.
- If a comet's path crosses Earth's orbit then it can lead to meteor showers.
- Sometimes, if a comet is traveling fast enough, it can leave its orbit and the solar system.

<u>Unpacking the kit – What you will need for each section</u>

<u>For Part</u> II. Where are Comets Found?

16 Instruction , 16 Handouts, and 32 Observation sheets

For Part IV. Making a Comet.

Materials for demonstration:

1 plastic bag containing materials for VSVS members to use for demonstration:
1 spoon, 4 pairs of gloves, 1 sandwich bag, 1 3.5 oz cup powdered dry ice, 1 3.5 oz cup with water filled to 50 mL level, 1 pie pan, 1 container sand/dust, 1 container charcoal, 1 dropper bottle ammonia

<u>Activity Set-up:</u>

Put the powdered dry ice into 16 3.5 oz cups (fill).
Pour water into 16 3.5oz cups to the 50 mL mark.
Put whole pieces of dry ice into 16 1 oz cups.

Materials: 16 spoons, 16 containers of sand/dirt (1 for demonstration)
3 containers of carbon (ground up charcoal) , 3 dropper bottles of ammonia
32 pairs of gloves, 16 sandwich bags, 16 plates, Goggles for all, 1 hammer

For Part VI. Seeing the Tails

16 1 oz cups for whole dry ice, water

For Part VII. Comparing Comets with Asteroids and Meteorites

Handouts
8 meteorites and 8 magnets

I. What are Comets?

Learning Goals: Students understand that a comet is leftover debris from the early formation of our solar system that orbits the sun.

Why is the science in this lesson important?

With increasing trips into outer space, scientists must learn more about what lies in our solar system and beyond. Comets are important because they are some of the oldest bodies in our Solar System, and they have traces of the nebula that formed the Sun and the planets.

Comets are left over debris from the early formation of our solar system.
Comets may have brought water and carbon-based molecules to earth. These are the molecules that make up living things
Most comets are too small to be seen without a telescope.

II. Where are Comets Found?

Learning Goals: Students learn where comets can be found.

Pass out Instruction sheets to pairs of students.

- Comets are part of our solar system. They orbit the sun.
  Tell students to look at the diagram (bottom image) of the solar system. Show them where the **asteroid belt** is and where **comets** can be found.
- Comets spend most of their time past Pluto in the Oort cloud or in the Kuiper cloud near Neptune.
- Gravity can pull a comet closer to the sun.

Your Notes:

____

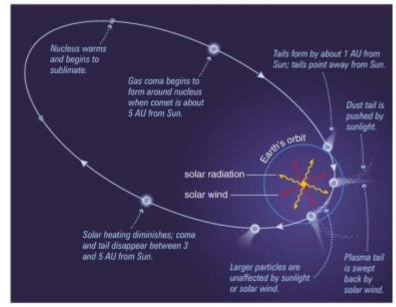
____

____

Have students trace the typical orbit of a comet (top image) It is very long and oval shaped.

Planets have a more circular orbit, so comets can sometimes cross the planetary orbits and collide with planets and their satellites.

- They have not been easy to study since they take a long time to orbit the Sun.
- It is rare to see one come close to earth, but it does happen. In 1986 the first picture of the interior of a comet was taken by the Giotto spacecraft. It was found that a comet's surface is not smooth, but very rough, full of holes, and lumpy.



III. What is a Comet Made of?

Learning Goals: Students learn the different parts of a comet.

1. A comet is a dirty ball of ice!
2. The comet has a small **nucleus** in the center– this may be only 1-10 miles across. The nucleus is the solid center, 50% is ice, and 50% dust and rock. 80% of the ice is made of frozen water. Another 15% is frozen carbon monoxide. The rest of the ice is frozen ammonia, carbon dioxide, and methane.
3. The nucleus is surrounded by a **coma –** this is formed when the comet gets close to the inner solar system.
4. The heat from the sun warms up the ices on the surface of the comet and creates gas and dust.
5. The comet may have 1 or 2 tails, depending on how close it is to the sun.
   a) The **dust tail** is produced as the ices evaporate and drag dust particles off the surface of the comet. They are pushed into a tail by radiation from the sun.
   b) The **ion tail** is produced by the solar wind which converts some of the comet's gases into electrically charged particles called ions.

   We see comets because the gas and dust reflect sunlight.

Tell the students that they will make a model of a comet using common materials.

- Water is present in comets as ice.
- Other ices include dry ice, which is frozen carbon dioxide, or CO_2.
- Ammonia or NH_3 is added as a liquid and gets frozen in the dry ice.
- Other frozen gases such as carbon monoxide and methane cannot be represented in this model.
- Sand or dirt represents the rock and dust.
- Charcoal (ground up) represents the carbon.

IV. Making a Comet.

Learning Goals: Students make a simulation of a comet from dry ice, dust, and rock.

All students must wear safety goggles and wear gloves. Divide the class into pairs.

Your Notes:

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___

___

Materials for demonstration:

1 plastic bag containing materials for VSVS members to use for demonstration:

1 spoon
4 pairs of gloves
1 sandwich bag
1 3.5 oz cup powdered dry ice
1 3.5 oz cup with water filled to 50 mL level
1 pie pan
1 container sand/dirt
1 container charcoal
1 dropper bottle ammonia

Demonstrate the procedure.

1. Add 50 ml of water to the sandwich bag
   Tell students this will become ice water, which is present in comets.
2. Add 2 tsp of non-organic material (dirt) to the water. Stir well until the water, and dirt are well blended to a muddy substance. Dirt represents the rock and dust in comets.
3. Add 1 spoon of ground charcoal. Stir well. Charcoal represents the carbon-based material.
4. Add a small squirt of NH_3 (ammonia). Continue to mix carefully.
5. Put on the thick working gloves.
6. Add 1 3.5oz cup of powdered dry ice to the bag and place bag on a pie pan. Agitate gently.
7. Wait until the mixture is almost frozen (it will stop bubbling).
8. Lift the bag up and shape it into a snowball by holding the bag tightly until the comet is able to hold its own shape. If necessary, add more water.
9. Unwrap the comet and display the result.

REVIEW SAFETY PROCEDURES:

All students must wear goggles and gloves.
Make sure that each group is supervised by a VSVS volunteer. If discipline is a problem, divide the class so that each group is supervised by one VSVS member.
Tell students that they must NOT touch dry ice with bare hands.
Make sure that the teacher is available for help, if needed.
Tell students they must NOT seal the plastic bag.

Distribute materials to each pair.

1 spoon
2 pairs gloves
1 sandwich bags
1 3.5 oz cup powdered dry ice
1 3.5 oz cup with water filled to 50 mL level
1 pie pan
1 container sand/dirt

Make sure that all groups keep a plate under the bag.
Tell students to:

1. Put on goggles and gloves.
2. Pour the 50 mL of water into the plastic bag.
3. Add 2 spoons of dirt.
4. VSVSers will add a small spoon of ground charcoal. Mix gently.

Your Notes:

___

___

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5. A VSVS member will add a squirt of ammonia.
6. Add the dry ice and wait until it starts to freeze (when it stops bubbling).
7. Form a ball by squeezing the bag tight. At some point the material will hold its own shape. Add more dry ice or water if needed.

Make sure that the students do not close the bag completely. Remind them that the carbon dioxide is subliming and the gas needs to dissipate, and the only way out at this point is out the top though the open hole in the bag.

What is happening?

- The CO_2 freezes the water, and all the other ingredients.
- Tell students to look at the thermometer diagram and compare the temperature of dry ice to the freezing point of water.
- Point out to students that the temperature of outer space is −270 °C (−454 °F).
- The water ice acts as the glue that holds everything together.

V. Observing the "Comets"

Learning Goals: Students observe changes in states of matter and how these transitions contribute to the formation of comets.

- Have students take the comet out of the bag by turning it upside down and placing it on the aluminum pie pan. Watch for a few minutes.
- Their "dirty snow ball" contains some dry ice that is subliming and spouting CO_2 gas.
- As time passes they will find that the comets will have craters. These craters come from the sublimation of the carbon dioxide. These pockets can be observed in real comets.
- The ejection of CO_2 gas can change the trajectory of the comets.
- At the end of the lesson a VSVS member will break the comets with the hammer. Students can observe holes in the middle of the comet, where the dry ice gas has sublimed.
- Tell students that some comets are similar in size to the one they have made. These fall apart when they get close to the sun.
  Other comets can be as big as earth. These are the ones that can survive several orbits around the sun.

__**Sublimation Information:**__ Write the different states on the board and the phase change that occurs between each state.

Solid ***melts*** **→Liquid** ***vaporizes*** **→Gas**
Gas ***condenses*** **→Liquid** ***freezes*** **→Solid**
Solid ***sublimes*** **→Gas**
Gas ***deposits*** **→Solid**

- Most substances have three states of matter that are observable at normal conditions (1 atmosphere of pressure and 20°C).
- Ask students what the 3 states of water are? *Ice (solid), liquid, and water vapor (gas).*
- Tell students that carbon dioxide also has 3 states, but that only 2 exist at normal conditions: a solid (called dry ice) and gas.
- Liquids can change to solids by **freezing**.

Your Notes:

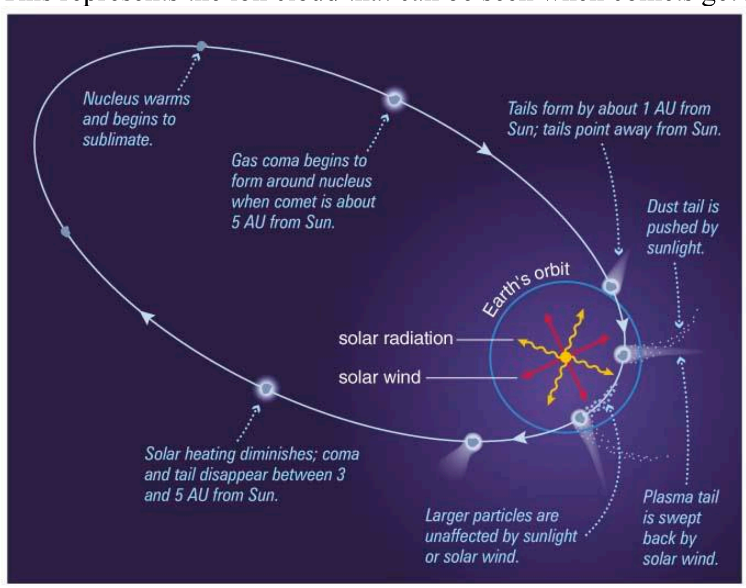
- Solids can change to liquids by **melting**.
- A liquid changes to a gas by **vaporization** (boiling).
- A gas changes to a liquid via **condensation**.
- **Sublimation** occurs when a solid changes state to a gas without going through a liquid phase. Dry Ice (solid CO_2), undergoes sublimation at normal conditions. Dry Ice sublimes at -78°C or -108°F.
- **Deposition** is the change from gas to solid. (One example is snow that forms in clouds. Water vapor changes directly to ice without first becoming a liquid.)

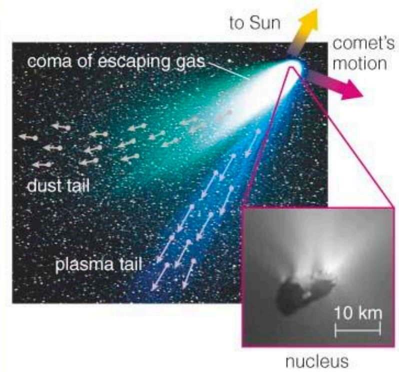
VI. Seeing the Tails

Learning Goals: Students observe changes in states of matter and how these transitions contribute to the formation of comets.

This can be done as a demonstration if needed

1. Give each group a few whole pieces of dry ice in a 1 oz cup. Add a little water to the cup to produce a cloud.
2. Tell one member of the group to hold the cup and move it in the air. Students should notice a tail behind the piece. This would represent the dust/gas cloud that is always behind the comet body.
3. Tell another student in the group to represent the sun and to blow gently across the path of the dry ice pieces. Students should see another cloud in a different direction. This represents the ion cloud that can be seen when comets get nearer the sun.





b (Above) Anatomy of a comet. The larger image shows a ground based photo of comet Hale-Bopp. The inset shows the nucleus of Halley's comet photographed by the *Giotto* spacecraft.

a (Left) This diagram shows the changes that occur when a comet's orbit takes it on a passage into the inner solar system. (Not to scale.)

Your Notes:

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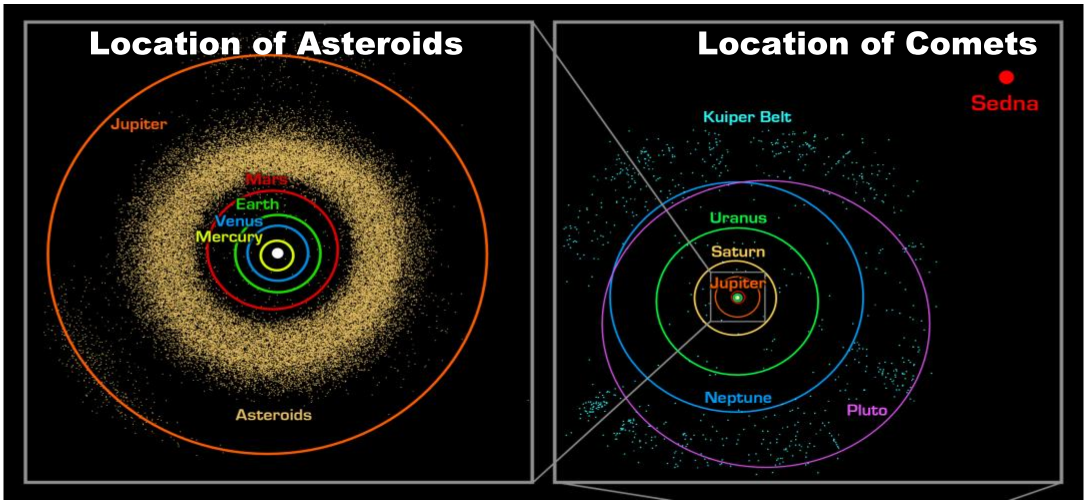
VII. Comparing Comets with Asteroids and Meteorites

Learning Goals: Students differentiate between comets and other celestial bodies.



Asteroids and meteoroids are small rocky bodies.
Asteroids do not have much ice and do not have tails.
Meteoroids are similar to asteroids but much smaller. They are probably pieces of asteroids.
Tell students to trace the orbit of the asteroid belt.
Point out that it is between Mars and Jupiter. Asteroid orbits can cross the path of Earth.
A meteorite is a meteoroid that has entered the earth's atmosphere.
Show the students the meteorite samples and tell them that it was found in Odessa, Texas.
Make sure all the meteorite samples are counted before leaving the classroom

VIII. Clean-up

1. Collect all dirty comets and place in trash bag.
2. Tie the bag and then poke a few holes in the top. This should prevent the bag from exploding.
3. Please take it out of the VSVS kit when you get back to the lab and hand it to a VSVS lab assistant.
4. Place all cups in another trash bag and return to the lab. They will be reused.

Lesson materials adapted from NASA web site. Lesson written by:
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Your Notes:

Comets Worksheet – ANSWERS

1. What are comets?
   Comets are left over debris from the early formation of our solar system.

2. Where are comets found?
   Comets are typically found near Neptune (in the Kuiper cloud) or out past Pluto (in the Oort cloud). Gravity can pull a comet closer to the Sun.

3. What is a comet made of?
   Comets are dirty balls of ice. They are mainly made of frozen water, frozen carbon monoxide, dust, and rock. (There is also some frozen ammonia, carbon dioxide, and methane.)

4. What is holding together the comet you made?
   The liquid water holds the comet together when it is frozen by the dry ice. The dry ice is cold enough (< -78°C) to freeze the water.

5. What is the temperature of outer space?
   -270 °C (-454 °F)

6. What caused the craters to form in your comet?
   The sublimation of dry ice. The carbon dioxide from the dry ice goes from solid to gas form. When the gas escapes, holes (craters) are left where there was once solid carbon dioxide.

7. What does the trail behind the piece of dry ice represent?
   It represents the dust/gas cloud that is always behind the comet body.

8. What happens when someone blows on the dry ice while it is moving?
   Another dust/gas cloud forms in a different direction.

9. What does this represent?
   The ion cloud that can be seen when comets get nearer to the sun.

10. How are asteroids and meteoroids different from comets?
    They do not have much ice and do not have tails. Meteoroids are smaller versions of asteroids. Asteroids have orbits much closer to Earth than comets.

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

Polymer Chemistry

Spring 2022

Goal: To introduce the concepts of polymers and cross-linkers and to investigate their properties.
Introduces/reinforces TASS: 5.PS1.1 Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.

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? *Solid, liquid, gas, non-Newtonian fluids*
2. What is a polymer? Give some examples. What makes polymers so useful? *Answer in section below*
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? *Answer in section below*
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? *Answer in sections IV and V*

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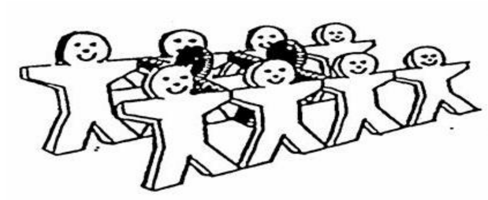
- Ask if the cross-linking made movement more difficult. *Groups should conclude that it is more difficult to move with the cross-linkers.*
- Thank the student volunteers and ask them to return to their seats.



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:

        - 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:

- 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.

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Your Notes:

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

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

Rates of Chemical Reactions

Spring 2022

Goal: To understand factors which affect the rates of chemical reactions - temperature, surface area (particle size), and concentration.
Introduces/reinforces TASS: 5.PS1.3 Design a process to measure how different variables (temperature, particle size, stirring) affect the rate of dissolving solids into liquids & 5PS1.4 Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties.

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. *Answer in sections II, III, IV*
2. What are some visual indications that a chemical reaction has occurred? *Color change, production of gas, precipitate formation*

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 10oz. clear plastic cups, 2 containers with 50mL of 20% vinegar, 5% vinegar solutions, 1 container of baking soda and 1spoon

Your Notes:

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 reactions 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

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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.

Materials – 1 sugar cube and 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.

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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, sawmills, 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 tablet or the crushed tablet. Tell them they should be ready to pour all the contents into

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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 prepared in a similar way.

Your Notes:

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 the reaction.

Your Notes:

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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.

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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**