**VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE**

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**Gluey Putty**

**Elementary grade**

**Spring 2013**

**Goal:**  To introduce the concepts of polymers and cross-linkers and to investigate their properties.

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**Lesson Outline**

**I. Introduction - Solids, Liquids, Gases, and Polymers**

Two VSVS volunteers conduct this section while other volunteers prepare the cups. Questions and activities are done to help students understand the difference between solids, liquids, and gases. A number of activities to demonstrate these differences and to illustrate polymers involve the use of student volunteers. Ask the teacher to help in selecting students who are willing to link arms.

**II. Skewering a Plastic Bag - Demonstration**

This demonstration illustrates both the elasticity of some polymers and the porosity of matter. Practice this one before teaching the lesson. It is not easy to put the skewer through the bag without having water leak. The trick is to have the skewer well-coated with glycerin and push the skewer through the bag slowly while twisting.

**III. Making Gluey Putty**

Students make Gluey Putty by mixing solutions of 50% water/glue and 4% borax. It is essential that the glue/water mixture is shaken before filling the cups. If the student’s mixture is too runny after kneading, add a small amount of the 100% glue and tell the student to knead some more.

**IV. Determining the Properties of Gluey Putty**

Students perform a number of tests on the Gluey Putty.

**V. Review**

Review the results of the tests in part IV in terms of properties of solids and liquids. Explain the classification of Gluey Putty as a non-Newtonian liquid.

Materials (for 25 students)

 1 plastic bag containing:

 1 paper clip chain (8 paper clips linked together in a chain), 1 sandwich bag, 1 milk cap

 1 plastic bag containing:

 3 plastic bags, 2 skewers (1 extra), 1small container of glycerin and one paper towel

 4 3.5 oz cups with line drawn on them at 50 mL mark

 25 1oz cups with 10 mL mark for borax

 25 10oz cups with sandwich bags inserted

 15 ziploc sandwich bags (extras in case some break - return unused bags)

 2 bottles (1L each) glue/water solution (50% glue; 50% water) **shake very well before using**

 1 small container of 100% glue

 1 16 oz soda pop bottle 4% borax solution

 25 sheets of wax paper

 25 popsicle sticks

 1 Borax box front

 25 shells (in Ziploc bag)

 1 trash bag

**Management Note:**

1. Two VSVS volunteers should conduct the Introduction section of this lesson while the other one or two volunteers prepare the cups for the Gluey Putty.
2. Shake the glue/water mixture very well before using - if this is not done, the gluey putty will be runny.
3. Count the students and prepare a cup for each student by pouring 50 mL of the glue/water solution into the ziplock bag inside each of the 10oz. cups.
4. Set these cups aside and pour 10 mL of borax into the same number of 1 oz. cups. Do not add too much borax – it will make the gluey putty runny.
5. **Another volunteer should put the following vocabulary words on the board:**

 **Solid, liquid, gas, polymer, non-Newtonian liquid**

**I. Introduction**

Materials:

1 plastic 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**

* Make a chart on the board to compare properties of liquids and solids.
* Ask students: What is the difference between solids, liquids, and gases?

Be sure to bring up the following points if they do not come up in the discussion:

* + **Solids** maintain their own shape; molecules are densely packed and move slowly.
	+ **Liquids** take the shape of the container; molecules are close enough to maintain shape but have more freedom to move.
	+ **Gases** fill the container; molecules have the greatest amount of movement (free to move anywhere in the container).
	+ Have students brainstorm about properties of each. Write their responses on the board under the appropriate headings.

Some answers can be:

|  |  |
| --- | --- |
| **A Solid** | **A Liquid** |
| has definite shape | has no definite shape (flows and takes the shape of a container) |
| can break into pieces | does not break into pieces |
| takes up a definite space | takes 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 |

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 help in selecting students who are willing to hold arms.**

**Solids**

1. Ask the 8 volunteers to come to the front and stand in a close cluster (not in two lines).
2. 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**

1. 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**

1. 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.

**Modeling Polymers**

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

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 large numbers 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, Plexiglas, 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**.
1. 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.

1. Break the human "polymer” chain into two smaller chains of four students each.
2. Ask the two chains to walk across the room.

Ask them if it is easier to move as an individual or as a chain.

1. Tell the groups to stand facing each other.
2. 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.)
3. Ask the entire group to walk across the room.

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. Skewering a Plastic Bag - Demonstration**

**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.

 Materials

 1 plastic bag

 1 skewer

 1 small container of glycerin

 1 paper towel

1. plate
2. Take one of the plastic zip lock bags and fill it about one-fourth full with water.
3. Take the skewer and dip the sharp end in the glycerol (small vial) to lubricate the end.
4. One VSVS member should hold the zip lock bag on an angle over a plate while another VSVS member uses a gentle twisting motion to push the skewer through the part of the zip lock bag containing water (not air).
5. Show the class that the zip lock 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.
6. Carefully remove the skewer while the bag is still over the plate, or over a sink – the water will now leak out! Put the skewer back in the kit box and discard the plastic bag.

**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.

**III. Making Gluey Putty**

Tell students they are going to make a polymer that uses cross-linkers to join the polymers.

(NOTE: Cups for this experiment should have been prepared for the students at the beginning of the lesson while two VSVS volunteers conduct the Introduction Section.)

Materials

 25 10 oz. cups (inserted with ziploc bags and glue mixture)

 25 1 oz plastic cups (with borax solution)

 25 popsicle sticks

 25 shells (in Ziploc bag)

 25 sheets of wax paper

 1 small bottle of 100% Glue

 1 Borax box front

**Note:** Do not put Gluey Putty in the sink! It can plug up the drain. Roll up the wax papers and toss them away after this activity. Vinegar will help clean up any putty that gets stuck in clothes or carpet. The putty will last for several days in the ziplock bag, but if allowed to dry, it forms a dense white solid.

**Background information on Gluey Putty**

Gluey Putty is a polymer compound that exhibits properties of both a solid and a liquid. Scientists call this a non-Newtonian liquid.

**Making the Gluey Putty**

Tell students that glue is a polymer that contains chains of polyvinyl acetate which have been dissolved in water. Show students the Borax box front and tell them that Borax is the cross linker in this activity. (Relate the human cross linker from the previous demonstration to the borax used in the Gluey Putty.)

Distribute the following materials to each student:

 1 sheet of wax paper

 1 10 oz. cup containing a ziploc bag with 50 mL of the glue and water mixture

 1 1 oz. cup containing 10 mL of borax solution

 1 Popsicle stick

 1 shell

 1 Observation Sheet

1. Have students place the wax paper on top of the desk to protect the surface.
2. Show students the bottle of the glue and water mixture and tell students that this mixture of half glue and half water is in the large cup on their desks.
3. Ask a student to describe the glue mixture.
4. Show the students the Borax box front cutout and explain that borax was added to water to make

Borax solution that is in the small cup on their desks. Ask a student to describe the borax solution.

1. Have students pour the borax mixture into the glue/water mixture and stir with a popsicle stick.
2. Have students close the ziploc bag and knead the gluey putty for a few minutes while it is still in the plastic bag.

**Note: Remind students to zip the bag shut before they knead the mixture to avoid spills. Students may need to open one corner of the bag, allow air to escape, and reseal the bag to facilitate the kneading process.**

**If the student’s mixture is too runny after kneading, add a small amount of 100% glue and tell the student(s) to knead it again.**

**IV. Determining the Properties of Gluey Putty**

**(Do as many of these as time allows.)**

Students should take the gluey putty 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 gluey putty. Some will stick to the side.

**Observation 1**

 • Squeeze half of the gluey putty between your hands to form a flat pancake. Grasp one edge of the pancake and hold it in the air at eye level. What happens?

Ask: Is the gluey putty behaving more like a liquid or a solid here?

 **Answer:** A liquid, because it flows.

**Observation 2**

• Take the sea shell and press the top of the shell (design side) into the flat Gluey putty. Remove the shell and look at the Gluey putty. What happens? (An imprint of the shell can be seen in the Gluey putty.)

• Place the Gluey putty on the left side of the wax paper and check again at the end of the period.

**Observation 3**

• Take the same piece of 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: Is this more like a liquid or a solid?

**Answer:** It droops in the middle; it is a more like a property of a liquid.

**Observation 4**

• Roll the gluey putty into a cylindrical shape again and pull it apart quickly.

Ask: Is this more like a liquid or a solid?

 **Answer:**  The gluey putty breaks; this is more like a property of a solid.

**Observation 5**

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

• Roll the gluey putty into a ball and drop it on a clean desktop.

Ask: Is this more like a liquid or a solid? (It bounces, but it will shatter if you throw it too hard.

 **Answer:** Bouncing and shattering are more like properties of a solid.)

**Observation 6**

• Roll the gluey putty into a ball and put it inside the ziploc bag. Zip the bag and place it on the

 desktop.

• Use the bottom of your fist and hit the ball in the bag.

 Ask: Is this more like a liquid or a solid?

 **Answer:** (The gluey putty breaks into pieces, which is more like the property of a solid.)

**Final Observation:**  Tell students that making the impression is a property of a solid. When the imprint disappears, that flowing demonstrates a property of a liquid. Tell students to try to make impressions with coins or small objects at home.

**Clean-up: Have students put the gluey putty into the ziploc bag and seal it so they can take it home.**

 **Return all unused supplies and used cups to the VSVS lab.**

**V. Review – Go over the observation sheet responses with students and ask**:

 *When does the gluey putty act like a solid? Liquid?*

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: Pat Tellinghuisen, Director of VSVS, Vanderbilt University

 Dr. Melvin Joesten, Emeritus Professor, Vanderbilt University

 Susan Clendenen, Teacher Consultant, Vanderbilt University

**Gluey Putty Instruction Sheet**

**Observation 1**

* Squeeze half of the gluey putty between your hands to form a flat pancake. Grasp one edge of the pancake and hold it in the air at eye level. What happens?
* Is the gluey putty behaving more like a liquid or a solid here?

**Observation 2**

* Take the sea shell and press the top of the shell (design side) into the flat Gluey putty. Remove the shell and look at the Gluey putty. What happens?
* Place the Gluey putty on the left side of the wax paper and check again at the end of the period.
* At the end of the activity, does the gluey putty behave more like a solid or a liquid?

**Observation 3**

* Take the same piece of 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.
* Is this more like a liquid or a solid?

**Observation 4**

* Roll the gluey putty into a cylindrical shape again and pull it apart quickly.
* Is this more like a liquid or a solid?

**Observation 5**

* Roll the gluey putty into a ball and drop it on a clean desktop.
* Is this more like a liquid or a solid?

**Observation 6**

* Roll the gluey putty into a ball and put it inside the ziploc bag. Zip the bag and place it on the desktop.
* Use the bottom of your fist and hit the ball in the bag.
* Is this more like a liquid or a solid?

**DETERMINING THE PROPERTIES OF GLUEY PUTTY**

Observation Sheet

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

Follow the instruction sheet to perform tests on Gluey Putty. After each test, determine if it is more like a solid or liquid and why.

|  |  |  |  |
| --- | --- | --- | --- |
| **Step #** | **Solid** | **Liquid** | **Why?** |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |  |

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

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**DETERMINING THE PROPERTIES OF GLUEY PUTTY**

Observation Sheet – Answers

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

Follow the instruction sheet to perform tests on Gluey Putty. After each test, determine if it is more like a solid or liquid and why.

|  |  |  |  |
| --- | --- | --- | --- |
| **Step #** | **Solid** | **Liquid** | **Why?** |
| 1 |  | X | flows like a liquid |
| 2 | X |  | can be imprinted |
| 3 |  | X | flows (droops) like a liquid |
| 4 | X |  | breaks |
| 5 | X |  | bounces, can break |
| 6  | X |  | breaks |

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

**Non-Newtonian liquid**