To close the yellow note, click once to select it and then click the box in the upper left corner.
To open the note, double click (Mac OS) or right click (Windows) on the note icon.

#8 Slime and Intermolecular Attractions

Submitted by: Melanie Stewart, Stow-Munroe Falls High School, Stow, OH 44224

I. INTRODUCTION

Description

This is a perennial favorite for students young and old which provides an excellent visual example of the strength of intermolecular attractions. The same type of interactions that causes water absorption in plastics causes liquids to turn into slimy masses. Students will also compare the difference in the physical properties of sheet and powdered polyvinyl alcohol (PVAl) with polyvinyl acetate (PVAc) and relate these to molecular structure and additives.

Student Audience

This activity is appropriate for high school chemistry, chemical technology, and university chemistry students.

Goals for the Experiment:

The student will:

- describe the strength of intermolecular attractions,
- compare physical properties of product materials,
- explain the variations in physical properties,
- explain special effect pigmentation, and
- work with water soluble polymers.

Recommended Placement in the Curriculum

This experiment is recommended for classroom use in the discussion of any of the following topics:

- molecular structure,
- intermolecular attractions,
- physical properties,
- testing and observations (scientific method), and
- polymers.

II. STUDENT HANDOUT

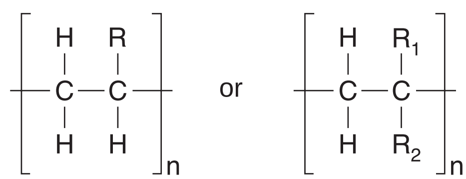
Slime and Intermolecular Attractions

Scenario

Polyvinyl alcohol slime is used as a drilling lubricant by the oil industry. Your company, Lubra-Slime, would like to expand its portion of this market and with this in mind has asked you to produce a variety of slime and slime-like formulations. The properties of these will then be investigated to see if they might make better lubricants than those currently available.

Background

Tremendous variation results from minor differences in the atomic structure of molecules. The polymers used in this activity are both from the vinyl family and vary only by the R group on the monomer. Polyvinyls are a large family of polymers that have the one of the general formulas shown below:



Polyvinyl alcohol (PVAl) has a hydroxyl group as the -R group and polyvinyl acetate (PVAc) has an acetate group. This variation will result in differences in physical properties of the polymers and in cross-linking behavior. Since the cross-linking occurs in part due to hydrogen bonding interactions, the mechanism is similar to water absorption in other non-water soluble polymers.

Learning to observe variations in properties, performing simple tests, and knowing terminology is important to the laboratory chemist and technician in any field of chemistry, including polymers. There are many similarities between all laboratory testing and terminology but each discipline also has a vocabulary specific to it. Using the materials created, some properties common to polymers such as flow viscosity, fracture, and cold flow will be determined. Not only are physical and chemical properties important to materials but aesthetics are very important also. The third material made includes special pigmentation which offers a unique look at this area of the industry.

Safety, Handling, and Disposal

- Although this activity is not unduly hazardous, proper care should be taken when handling any chemical.
- Chemical resistant goggles should be worn at all times.
- Read the MSDS for all chemicals being used to determine any precautions that should be followed.
- Dispose of used reagents according to local ordinances.

Materials
Per student or group

Each preparation
- 50-mL beaker or small paper or plastic cup (3- or 5-ounces)
- (optional) food color
- boiling water
- graduated cylinder or other volume measuring device
- stirring rod or craft stick
- 4% solution of sodium borate
- eye dropper or pipette
- ziptop bag

Part 1: Slime
- sheet of polyvinyl alcohol film
- balance

Part 2: Gluep
- distilled water
- white glue

Part 3: Pigmented Slime
- 4% solution pigmented polyvinyl alcohol
- 4% solution of pigmented sodium borate

Questions
- additional materials as needed for tests in Question 1.

Procedure
Part 1: Slime
1. Determine the mass of the sheet of PVAl and then place it into the small container.
2. Calculate the amount of water necessary to make a 4–5 %-by mass/volume solution of PVAl and measure it out.
3. (optional) Add several drops of food color to the boiling water.
4. Add the correct amount of boiling water to the PVAl sheet in a 50-mL beaker. Stir continuously to dissolve. Allow to cool.
5. Add 4% sodium borate solution several drops at a time, keeping track of the amounts and stirring well after each addition, until a slimy mixture is obtained. Knead the slime briefly to form a uniform consistency.
6. Transfer mixture into a small ziptop bag.
7. Record the amount of sodium borate used.

Part 2: Gluep

1. Measure 12.5 mL of white glue (polyvinyl acetate) into a small container.
2. Add 12.5 mL of water and stir to mix.
3. (optional) Add several drops of food color and stir until homogeneous.
4. Add 4% sodium borate solution dropwise (about a milliliter at a time), keeping track of the amount and stirring well after each addition until the mixture globs and completely pulls away from the sides of the beaker. This will take a great deal more sodium borate and stirring than was needed in Part 1.
5. Knead gluep briefly to form a uniform mass.
6. Transfer material to a small ziptop bag.
7. Record the amount of sodium borate used.

Part 3: Pigmented Slime

1. Measure 25 mL of pigmented 4% PVAl solution into a small container. Do not add pigment (food color) as this solution already has a special effects pigment added.
2. Again add 4% sodium borate solution until the slime is made, keeping track of the amount and stirring extensively after each addition. Knead to a uniform consistency.
3. Transfer the material to a ziptop bag.
4. Record the amount of sodium borate used and answer the following questions. What color do you see when you look at the pigmented slime? Hold the pigmented slime up to the light. Now what do you see?

Questions

1. Describe each material, using a chart and the physical properties of transparent/translucence, color, texture and two others. Develop five simple tests for the each of the three samples such as stretch, fracture, cold flow, viscosity, and/or others of your choice. Write the procedure followed and record the results in the data chart.
2. Describe reasons for the differences in physical properties of slimes (PVAl polymers) and gluep (PVAc) .
3. What do you think causes the color change in the third sample?
4. Draw the two different monomers involved.
5. Draw structures for two possible ways that borate can interact with PVA molecules to induce gellation.
6. What would happen if you added acid to the gels?

References

Mark, J., Eisenburg, A., Graessley, W., Mandelkern, L., & Koenig, J. *Physical Properties of Polymers;* American Chemical Society: Washington, D.C., 1984.

Richardson, T. *Industrial Plastics: Theory and Application;* Delmar Publishing, Inc.: New York, 1986.

Sarquis, A.M. “Dramatization of Polymeric Bonding Using Slime,” *J.Chem.Educ.*, 1986, 63, pp. 60-61.

Shah, V. *Handbook of Plastics Testing Technology;* John Wiley & Sons: New York, 1984.

III. INSTRUCTOR NOTES

Slime and Intermolecular Attractions

Purpose

This activity investigates intermolecular attractions and how variations in molecular and atomic structure affect them. The student will also investigate physical properties of product substances including viscosity and cold flow by performing simple, self-designed tests.

Time Required

This investigation of slimes takes two 50-minute class periods or one long lab session.

Suggested Group Size

This investigation can be done with students working as individuals or in small groups.

Materials

Per student or group

<u>Each preparation</u>

- 50-mL beaker (Disposable plastic beakers are reasonably well graduated and accurate enough for this activity. Also, one beaker per person is fine and students can wash the beaker between parts.) or small paper or plastic cup (3- or 5-ounces)
- (optional) food color
- boiling water
- graduated cylinder or other volume measuring device
- stirring rod or craft stick
- 4% solution of sodium borate [4 g of sodium borate dissolved in 100 mL of hot (distilled) water. Prepare enough for 25-30 mL per student. One third will need to be pigmented. See below.]
- eye dropper or pipette
- ziptop bag

<u>Part 1: Slime</u>

- sheet of polyvinyl alcohol film (This can be purchased from craft stores under the trade name Sulky Solvy or through hospital supply firms that sell dissolvable laundry bags. In order for the students to have approximately the same volume of materials to test, cut samples of PVAl sheet that mass approximately 1.25 g.)
- balance

<u>Part 2: Gluep</u>

- distilled water
- white glue

<u>Part 3: Pigmented Slime</u>

- 4% solution pigmented polyvinyl alcohol (Prepare a 4% solution of PVAl by mixing 4 g per 100 mL of distilled water. Heat slowly, stirring constantly until PVAl dissolves. Using a

stirring hot plate works best. Heat in an Erlenmeyer flask with an inverted beaker to help minimize evaporation. Allow to cool before using. To save time, you can purchase solution premade from a science supply house. To pigment add 0.1g bromophenol blue and 0.4g sodium fluoroscein salt to 1 L of PVAl solution.)
- 4% solution of pigmented sodium borate (For a liter of pigmented sodium borate, add 0.1 g bromophenol blue and 0.4 g sodium fluoroscein salt.)

Questions

- additional materials as needed for tests in Question 1.

Safety, Handling, and Disposal

- Although this activity is not unduly hazardous proper care should be taken when handling any chemical.
- Chemical resistant goggles should be worn at all times.
- Read the MSDS for all chemicals being used to determine any precautions that should be followed.
- Dispose of used reagents according to local ordinances.

Points to be Covered in Pre-Lab:

- Intermolecular attractions especially hydrogen bonding.
- Even though the chemicals used are not duly hazardous, remind students to wear goggles. Student may also want to wear gloves to prevent their skin from drying out from the sodium borate solution. Review MSDSs on all chemicals including the pigments.
- Materials (slimes and gluep) made may last a very long time if kept in sealed bags and in the refrigerator. However, slimes and even PVA solution mold relatively quickly.
- Organic nomenclature may need to be reviewed to know and understand the alcohol and acetate groups structures.

Procedural Tips and Suggestions

- Remind students to keep track of sodium borate used. The student may want to use a 10-mL graduate for keeping track. Pour an exact amount in the graduate and record. When the material is made, determine the amount of sodium borate used by difference.
- What color will the students see when they look at the pigmented slime? *Green*
- What color will the students see when they hold the pigmented slime up to the light? *Red*

Plausible Answers to Questions

1. Describe each material, using a chart and the physical properties of transparent/translucence, color, texture and two others. Develop five simple tests for the each of the three samples such as stretch, fracture, cold flow, viscosity, and/or others of your choice. Write the procedure followed and record the results in the data chart.

A:

a. Cold flow measures the deformation of a material under the stress of a load over time. In the procedure outlined here, gravity is the load exerting the force on the sample.

- Make a 1.0–1.5 cm ball from a sample of the material. (Use the same size ball for each of the different materials.)
- Place the ball on a smooth horizontal surface and wait 20 minutes.

- Record the diameter of each material at the end of the 20 minutes. The data chart entry would be listed as cold flow in units of cm for each sample.

b. Flow viscosity is usually measured in g/10 min. but this can be modified. For example, how quickly does the sample flow through an inverted 20-oz bottle that has been cut like a funnel?
c. Fracture is characterized as being brittle or ductile. A sample of each can be pulled to see the results. The slower the pull the more ductile the fracture will be.
d. Reaction to household chemicals is also an appropriate test. Chemicals to test might include salt, sugar, soap, vinegar, ammonia, etc.
e. Solubility in water is another simple test that can be suggested.

2. Describe reasons for the differences in physical properties of slimes (PVAl polymers) and gluep (PVAc).

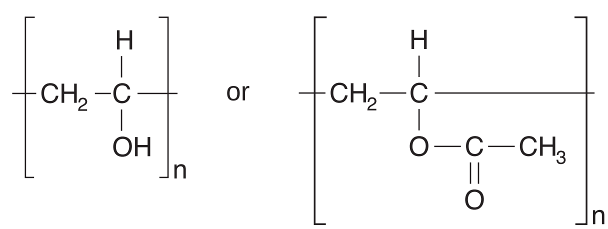
A: Reasons include differences in molecular structure, variations in concentration, changes in mixing techniques such as stirring more, using different amounts of sodium borate, etc. The PVAl film may have an additive to help in the processing of the sheet form, therefore it may not be as thick as the pigmented slime. The amount of sodium borate added may be used as an indicator here. If we assume that the concentration of the samples is the same, the amount of sodium borate also can be related to the number of secondary interactions sites. PVAc has the unshared electrons of 2 oxygen atoms per monomer unit, whereas PVAl only has 1, therefore more sodium borate is used.

3. What do you think causes the color change in the third sample?

A: The pigments used mask one another. The fluorescein (red) is not visible until light passes through the sample—then it becomes the predominant color seen. The red is a transmitted color. When light passes through the material containing the (red) fluorescein particles, they absorb blue, green, yellow, etc. light and only transmit red. The green is due to the fluorescence of the fluorescein. The visible and UV light absorbed by fluorescein is re-emitted as greenish-yellow light. The bromophenol blue is added to give a blue color that, together with the yellowish fluorescein glow, makes a nice green.

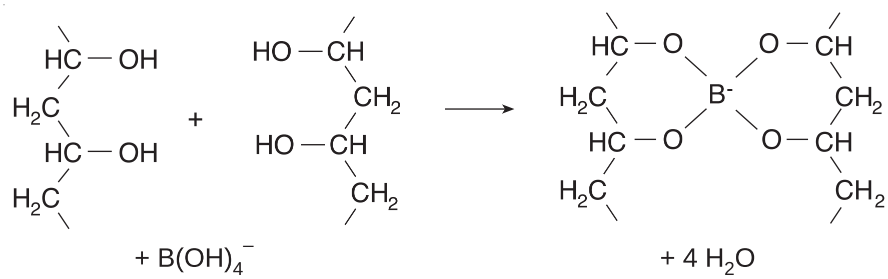
4. Draw the repeat units for the polyvinyl alcohol and the polyvinyl acetate.

A:

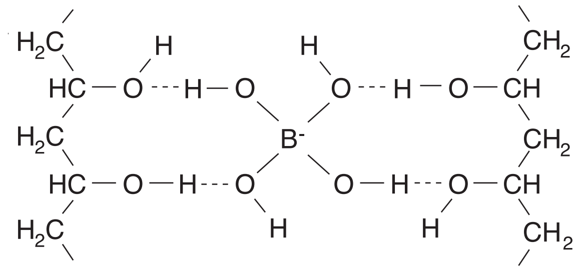


5. Draw structures for two possible ways that borate can interact with PVA molecules to induce gellation.

A: Although the actual mechanism may be more complex, both covalent bonding and H-bonding occur between the polyvinyl alcohol and the borate. The covalent bonding involves the loss of a water molecule between the borate ion and each alcohol group:



Hydrogen bonding is thought to occur in an analogous manner as shown below. The dashed lines represent the H-bonds due to the partial negative charges on the very electronegative oxygens and the partial positive charges on the much less electronegative hydrogens.



In both cases, the alcohol groups involved may be on the same polymer chain or may be on different polymer chains. The net result is a 3-dimensional cluster of polymer chains held together by the interactions with borate. The product is a gel because most of the volume within the cluster is filled with water molecules. The specific, detailed properties of a Slime sample will vary with the amount of interaction between the polyvinyl alcohol and the borax. This in turn is dependent on the relative amounts of the ingredients and the manner of mixing.

6. What would happen if you added acid to the gels?

A: The gels will slowly de-gel when exposed to an acid such as vinegar. (The older the gels, the longer this process takes. Fresh gels should only take a few minutes.) If a base such as aqueous ammonia is added to the de-gelled material, the mixture will re-gel as the acid is neutralized. The H+ ions in the acid evidently interfere with the cross-linking, possibly by attracting the -OH groups on the borate ion. The three-dimensional cluster breaks down and the gel is lost.

Extensions and Variations

1. Try varying the amount of borax solution added to see how the properties are altered.
2. Add 10–20 drops of vinegar to a small amount of freshly made gluep and stir. Then add 10–20 drops of household ammonia and stir. (Do not let students play with the re-gelled gluep after this treatment; some acid or base may remain.)

References

Mark, J., Eisenburg, A., Graessley, W., Mandelkern, L., & Koenig, J. *Physical Properties of Polymers;* American Chemical Society: Washington, D.C., 1984.

Richardson, T. *Industrial Plastics: Theory and Application;* Delmar Publishing, Inc.: New York, 1986.

Sarquis, A.M. "Dramatization of Polymeric Bonding Using Slime," *J.Chem.Educ.*, 1986, 63, pp. 60-61.

Shah, V. *Handbook of Plastics Testing Technology;* John Wiley & Sons: New York, 1984.