Slime:
Classroom demonstration of property change due to crosslinking
(More fun than you should ever have teaching science or technology)

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Abstract
This fun experiment explores what slime can offer in terms of the scientific exploration of a variable. PVA is 96% water, Borax solution is 96% water. When mixed together they are still 96% water. Here, we examine the variations students can get by mixing the polymer and the borax “cross linker” together. The resultant slime will be everything from runny to hard and brittle. The lab demonstrates plastic flow vs. elastic behavior, hydrogen bonding, viscosity, and how this simple polymer demo applies to metals, ceramics, and composites.

Module objective
Demonstrate that variables in preparation can make a big difference in the properties of a product, in this case a mixture of a polyvinyl alcohol or a glue with a borax solution at different compositions.

Student learning objectives: Students will be able to
Identify plastic flow vs. elastic behavior
Demonstrate variations in viscosity as a function of composition
Specify the effect of crosslinking on properties
Recognize property differences between different material compositions

MatEd Core Competencies covered:
0.B Prepare tests and analyze data
1.C Apply laboratory skills
5.A Apply safe and environmentally appropriate methods to chemical handling
5.B Demonstrate knowledge of chemistry fundamentals
7.L Explain how plastics and polumers differ from other materials
16.A Explain effects of processing and manufacturing variations on material properties

Key words: Slime, Gak, Plastic flow, Crosslinking

Grade levels: grades 6 - 14

Mode of Presentation: Classroom Demonstration with student group involvement

Time required: One class period

Pre-requisite knowledge: None

Table of Contents

Materials and supplies needed:

- 4% polyvinyl alcohol (PVA) solution - 50 mL per group
- 4% sodium borate solution (borax)
- 5 oz. paper cup
- wooden craft stick
- food coloring
- plastic baggy

For safety:

- Lab aprons and safety glasses/goggles should be worn.
- The borax and the PVA will burn the eyes. Hands should be washed at the end of the lab.

Curriculum overview and notes for the instructor:
By having different groups use different amounts of sodium borate solution, students should be able to more easily determine the effects of cross-linking on the properties of the polymer. The more sodium borate used, the more cross-linking that occurs. Each batch of slime is 96% water but they do not have the same viscosity. It should be emphasized that the students did not make polymer chains. The polymer chains are dissolved in the water in the PVA solution; they were already there. The sodium borate just “ties” the polymer chains together making it a more cohesive mass.

Polymer chains are formed by covalent bonds which are strong bonds. In making slime, individual polymer chains are “hooked” together by weak hydrogen bonds. It is evident that this cross-linking is weak because of the ease with which the slime pulls apart. It is sort of like “tying” together strong strands of string with limp strands of cooked spaghetti. Even though this cross-linking is weak, it does alter the properties of the polymer.

Have the students leave some of the slime stretched out on a counter overnight. The water will evaporate and the PVA will become a dry, brittle film that is mostly transparent. Also, pour some PVA solution that has **not** been cross-linked with borax on the counter. It will dry into a more flexible film much like the water soluble laundry bags used by hospitals. It is possible to mass a sample of each team's slime both before and after drying and calculate the percentage of water in each. This will provide evidence that each type of slime was indeed 96% water and that the difference in properties was not due to the amount of water but to the amount of cross-linking.

An observation that the students can make is how cool the slime feels. As the slime is stretched it has more surface area exposed to air and the evaporation rate of the water is increased. What they are feeling is the effect of evaporative cooling.

The PVA solution can be made using a stirrer hot plate. But it is much faster and easier to make it using a microwave oven. Do not let the solution boil whichever method you use. Boiling will alter the properties.

A beaker may be used to make the PVA solution. Add 4 grams of PVA powder to 96 mL of tap water and stir. The PVA will suspend briefly but will not dissolve until heated. To make larger amounts just multiply the amount of ingredients by the appropriate factor. Cover the beaker with microwaveable plastic wrap and stir between heating segments. Microwave for 2 - 3 minutes at a time depending on the amount of solution. Heat to 80°C. Microwave an additional minute at a time if needed. The prepared solution should be clear and somewhat viscous. The PVA solution will often still look slightly cloudy at this point but it will clear upon sitting. Do not heat above 80°C. The solution stores well in the refrigerator until needed.

The PVA solution is sticky. Have the students try to figure out a way to measure the required amount of PVA without putting it into a graduated cylinder. This is a quick, simple opportunity for them to problem solve. The students can measure 50 mL of water in a graduated cylinder, pour it into a cup, and then mark the fluid level. Pour out the water. Add PVA to the mark. Some students will usually figure this out for themselves. It really saves on clean-up. It is also helpful to store the PVA solution in PETE bottles (#1 recycling) with nipple-style caps. These are much easier to pour from and create less mess. Students often add too much food coloring. To avoid this problem, add the food coloring to the bottles of PVA solution prior to the lab.

Module Procedure: Polyvinyl Alcohol (PVA)
Divide students into 5 groups. Assign each group one of the following "recipes":

Team	PVA	Sodium borate solution
1	50 mL	1 mL
2	50 mL	2 mL
3	50 mL	4 mL
4	50 mL	6 mL
5	50 mL	10 mL

1. Add PVA to paper cup.

2. Stir in food coloring if desired. (just a few drops)

3. Add sodium borate solution - stirring quickly making sure to scrape the sides and bottom using the wooden craft stick.

4. Pour entire contents of the cup into a plastic baggy and knead.

5. Take slime out of baggy and “investigate” properties.

6. Have groups compare properties of the different slimes:
   - bouncing
   - stretching slowly
   - stretching quickly
   - letting it “pour” from one hand to another
   - flow rate through a wide mouth funnel

Have the students record the appearance and characteristics of the PVA at each step. This method of doing the slime lab allows the students to work as teams and then causes the teams to interact to make comparisons. The students sometimes struggle to find the words to describe the slime in step #6 - encourage them to devise some sort of chart or graphic organizer to record their results/conclusions.

Alternate Experiment # 1: GAK

An alternative to making PVA slime is to make gak. Gak uses Elmer’s glue (either school glue or wood glue) which contains polyvinyl acetate instead of polyvinyl alcohol. The same principles apply and the same outcomes can be achieved. We do both labs for reinforcement. The gak is opaque whereas the slime is transparent; both can be dyed with food coloring. The gak will give more of a silly putty consistency, although it is sometimes less uniform than alternative #2 below.

With the PVA slime we have 5 different “recipes”. With gak, we use 3 different “recipes” which are as follows:

#1
15 g glue
15 mL water
10 mL sodium borate solution

#2
15 g glue
30 mL water
10 mL sodium borate solution

#3

15 g glue
10 mL sodium borate solution

As in making slime, add food coloring to the glue and water before adding the sodium borate solution. The directions are basically the same for slime and gak. Have the students perform the same "tests" on the gak as they do on the slime.

Alternate Experiment #2: PVA plus GAK

For a hybrid experiment, use 20 ml PVA and 20 ml glue plus the sodium borate solution as cross-linker. It makes a product with really nice properties, and it's fun to play with.

Evaluation Packet:

Student evaluation questions (discussion or quiz):

1. What percent liquid vs. solid were in each mixture?
2. When combined what was the liquid vs. solid %.
3. How did the viscosity change as a greater amount of Borax solution was added?
4. When all water is evaporated what should be the mass of the remaining material ?
5. When all water is evaporated describe what you think the remaining solid will look like and what will be its physical characteristics.

Instructor evaluation questions:

1. At what grade level was this module used?
2. If used, did the lab add to student learning? Please note any problems or suggestions.
3. Was the background material sufficient for your background? Sufficient for your discussion with the students?
4. Did the lab generate interest among the students?
5. Please provide other comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the module clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?