Experiment Guide

Playful Polymers

Aim: To learn how polymers behave through the creation of a non-Newtonian fluid … Slime!

Introduction to the subject matter of the experiment:

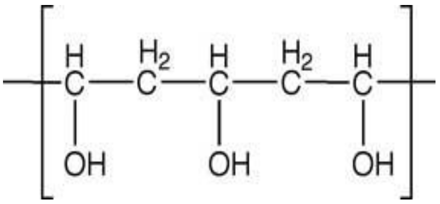
Many children know Slime as a toy you can buy in your shops.

Slime consists mainly of water gelatinized with a thickening agent. Slime has to form a coherent body to prevent it from coming apart in little pieces like jelly during play – how and with what this is done will be demonstrated in an experiment.

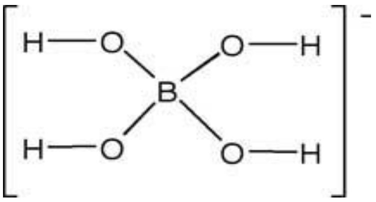
Theoretical background:

A *polymer* is a chain of molecules. The repeating unit in a polymer is called a monomer.
The terminology comes from Greek: mono= one, poly= many.

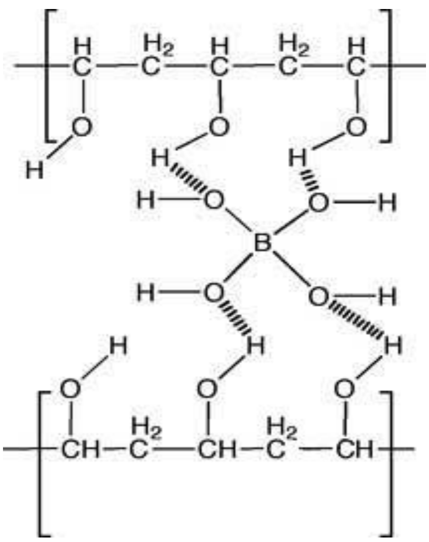
Glue contains the polymer polyvinyl alcohol (PVA).
Cross-linking is made possible by adding borax, $Na_2B_4O_7.10H_2O$ (sodium tetraborate).



Polyvinyl alcohol (PVA)



Borax forms the borate ion when in solution.



The borate ion can make weak bonds with the OH groups in the polymer chains so it can link the chains together. This is called cross-linking.

In its natural form, borax (sodium tetraborate decahydrate – $Na_2B_4O_7$ x 10 H_2O) forms large, in most cases colorless crystals. In the past it was used as a water softener in detergents due to the fact that it can also produce metallic ion complex bonds.

It is also used as a fluxing agent for welding and soldering, where it destroys the oxide film on the surface of the metal being machined, in doing so making the metal accessible for the soldering process. Borax is also used in the production of glazing for sheet metal ("enamel") and porcelain crockery or earthenware.

It serves as the starting material in the production of perborates, which can be found in some detergents and bleaches due to their bleaching effect.

Knowing just how much Borax solution to add is the trick to this experiment. If you add too little, your slime will contain excess glue (the polymer part) and it will be sticky. If you add too much, your slime will be very wet (too much 'cross-linking').

Other interesting facts:

When polymers are made of amino acids, they are called proteins.
Synthetic (man-made) polymers can be made of other monomers to make materials such as plastics (eg polystyrene, polyethylene), textiles (ie nylon, polyester). Many other materials such as chewing gum, Jell-O, elastic bands are also polymers.

Slime is a non-Newtonian fluid that is dilatant – ie under stress, the material dilates or expands. Other well-known stress-thickening materials are quicksand, wet sand on the beach, some printer's inks, starch solutions and 'Silly Putty'. Dilatant materials tend to have some unusual properties.

• Under low stress, such as slowly pulling on the material, it will flow and stretch. If careful, you can form a thin film.

• Pull sharply (high stress) and the material breaks.

• Pour the material from its container then tip the container upwards slightly, the gel self siphons.

• Put a small amount of the material on a table top and hit it with your hand, there is no splashing or splattering.

• Throw a small piece onto a hard surface; it will bounce slightly.

Adding acid to the slime breaks the cross-linking producing a liquid with lower viscosity. Adding alkali reverses the process and the slime should be regenerated.

Various types of slime have been manufactured. In this investigation you will use the polymer polyvinyl alcohol, which is reasonably cheap and is readily available from suppliers because it is widely used as a thickener, stabilizer and binder in cosmetics, paper cloth, films, cements and mortars. In ethanol solution polyvinyl alcohol solution dries to leave a thin plastic film that is useful in packaging materials, especially as it is biodegradable.

Lesson Introduction:

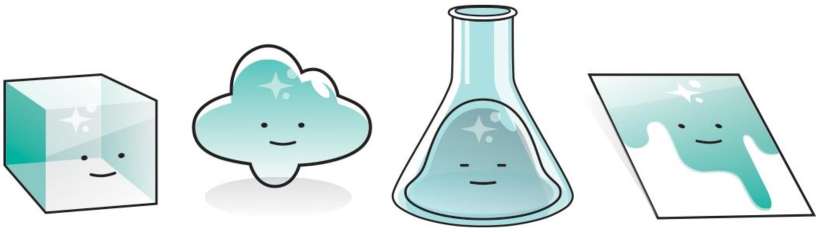
Welcome to the BASF Kids' Lab. BASF is the world's largest chemical company and they run Kids' Lab programs like this all around the world. Can anyone think why? BASF wants children all over the world to understand and enjoy experimenting with chemistry!

Has anyone heard that word before: Chemistry? What do you think it means?

Chemistry is the science of matter. Have you heard of the word "matter" before? What is matter? Matter is a scientific word for <u>stuff</u>. Chemistry is a science that explores the composition of substances and their properties and reactions. In other words, Chemistry is a science that explores how different stuff behaves. Take a look around you and see if you can see something that is made from chemistry. (Have kids guess what is made from chemistry) Do you think there is chemistry in you? Well there is – your body is made of six major substances: oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus. This stuff comes in many different forms.

Has anyone heard of the States of Matter? Yes, Solids, Liquids and Gases are the three states of matter.

Let me introduce you to morpH, the face of Kids' Lab. morpH can move through the three states of matter with ease. Is there a substance that you know of, like morph that can easily shift from solid to liquid to gas (and back again)??? Water!! That's right!! Water is one of the most important substances on earth. Not only does water make life possible, but it can be used to create interesting substances. We will be exploring some strange matter today!!



morpH and I would like you to explore some playful polymers.

Let's first understand some chemistry vocabulary terms. Do you know what the smallest bit of matter is called? Yes, an **<u>atom</u>** … That's right! **Atoms** can come together to form **<u>molecules</u>**. Today we will be exploring **<u>polymers</u>**. **Polymers** are chains of molecules. Each individual piece of the polymer chain is called a **<u>monomer</u>**.

Let's create a polymer chain. On your tray you will find several pipe cleaners. Turn at least 4 pipe cleaners into circles (these are your monomers). Now use some other pipe cleaners to link your monomers into a chain. This is your polymer.

Sometimes polymer chains can link up with neighboring chains. This is called cross-linking. Be creative and cross-link with your neighbor's chain.

Now let's see how your polymers behave. Does it bend? Can it stretch?
What happens when you put force on the chain? Does it break apart? Can you reattach the broken pieces?

(*Note: Invite some volunteers to join you in the front of the room while participants make their pipe cleaner chains at their work stations. 6-8 volunteers work well. Have them form two rows linking arms. Ask them to move from side to side and back and forth. Then, have the back row reach across to the front row and cross-link. Now have them try to move back and forth and side to side. Did it get harder or easier to move?? Also demonstrate how you can detach and reattach the links.)

Thank you to our volunteers. Now, let us put our model polymers aside for right now. Later we will revisit our models. It is time to experiment! But first …

Lab safety is a must! In order to safely explore Chemistry, we need to follow proper lab safety. How do you think we are going to do this? Chemists follow very strict procedures to protect themselves and they include:

- Gloves
- Goggles
- Lab aprons
- Point out any safety features in the classroom (ie. Eyewash or emergency shower)
- Mention housekeeping rules – NO EATING OR DRINKING
- Mention location of bathrooms

Now, put on your gloves and goggles and let's get started!

The Experiment

Materials:

For the Instructor:
2 large beakers (1000 ml beakers work well)
2 Stirring Rods
2 Tablespoons
1 hot plate with magnetic stirring capability
Glue/Water Solution: Equal parts Elmers Glue and water (Mix thoroughly. Transfer into participants beakers in 5 tablespoon amounts quickly to avoid settling.)
Borax Solution: 1000 ml of water and 3 tablespoons of Borax Laundry Powder (Using a hot plate and magnetic stirrer decreases the time for Borax to dissolve.)

Each tray needs:
1 400 ml beaker containing 5 tablespoons of the glue/water solution
1 plastic stirring rod
1 small polypropylene cup (medicine cup) with 10 ml of Borax Solution
1 small plastic bag or plastic container to allow participant to take slime home
Food coloring

Experiment steps

**Instructor: Please review the items participants will be using on their trays.*

Step 1
Add food coloring to the glue/water solution. (*Please only add 2 or 3 drops of food coloring to the solution. Adding more will cause staining of hands.)

Step 2
Stir until there is no white remaining in the solution.

Step 3
Add the 10 ml of Borax Solution to the now colored glue solution. (Add this slowly and continuously stir.)

Step 4
Stir until all of the liquid has been incorporated.

Step 5
Remove the ball of slime and roll in the palms of your hands until the slime dries slightly and becomes more pliable and less sticky.

Now let's observe!

- Pull the slime slowly. What happens?
- Try to rip the slime. What happens? Can it be put back together?
- Roll it into a ball. Try to gently bounce it on the tabletop. Does it bounce?
- Set the ball on the tabletop. What happens?

Let's compare!

Now that you have created your playful polymer, how does your model compare to the real thing??

Summary:

An atom is the smallest unit of matter. Atoms come together to form molecules. Polymers are chains of molecules. Each individual piece of a polymer chain is called a monomer. Sometimes polymer chains can link up with neighboring chains. This is called cross-linking.

A colorful and soft mass with which you can play and which is unpleasant to touch – that's slime!
Slime consists mainly of water. A thickener prevents it from disintegrating into little bits.
Glue contains the polymer polyvinyl alcohol (PVA).
Cross-linking is made possible by adding borax, $Na_2B_4O_7.10H_2O$ (sodium tetraborate).

Water: a raw material for slime and many other things

For BASF, water is one of eight raw materials, from which all the company's basic, intermediate and finished products are manufactured – and thus a priceless basic material of the chemical industry.