

## Silly Putty: Synthesizing a Polymer

Having the students blow air into the  $\text{LN}_2$  causes water vapor to condense out making “clouds”. Adding Elmers School glue (or generic brand School Glue) to a water/borax solution causes a chemical reaction between the glue molecules (polyvinylacetate) and the borax molecules ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ) to produce a highly flexible, cross-linked polymer. This polymer is similar to silly putty (real silly putty is a polymer based on organosiloxy groups and will not dry out like this material).

### Supplies Needed

- 1 gallon borax water solution in some sort of container (you provide)
- eight 4oz school glue containers for a class of 30 students (you provide)
- roll of paper towels (you provide)
- 15 disposable plastic bowls (you provide)
- 30 zip lock plastic bags to store “silly putty” (you provide)
- borax in plastic bag (we will provide)

### Recipe

2-3 tablespoons of borax ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ) mixed in 1 gallon of water. It doesn't hurt to add too much borax, as it will not dissolve and just sit on the bottom of the container. If you don't add enough borax (less than 1 teaspoon, for example) there may not be enough borax present to fully polymerize the glue molecules. This will lead to a very gooey, slime-like product. Pour enough borax/water solution to cover the bottom 1/3 of whatever bowl you are using to prepare the “silly putty”, and squirt in as much Elmer's Glue as you want to make polymer. Note that if you are going to add a lot of Elmer's Glue (more than 8 oz, for example) you will need to have at least a pint (~500 mL) of solution present.

Vigorously mix together the glue and borax water mixture with your fingers while keeping the polymerizing glue “silly putty” in the borax water solution. If you squirted the glue into the borax water solution as a thin stream and it sank into the solution, you should only have to mix it vigorously with your fingers for about 30 seconds to 1 minute. If you poured the glue into the solution as a big blob, then it will take considerably longer to mix the borax into the glue and get it all to polymerize into “silly putty.” Every now and then, pull the blob of glue/silly putty out of the borax water and kneed it up and see if any pockets of liquid glue still exist. If you see liquid glue squirting out of the “silly putty,” then it has not yet fully reacted with the borax water. Put it back into the solution and kneed it up some more.

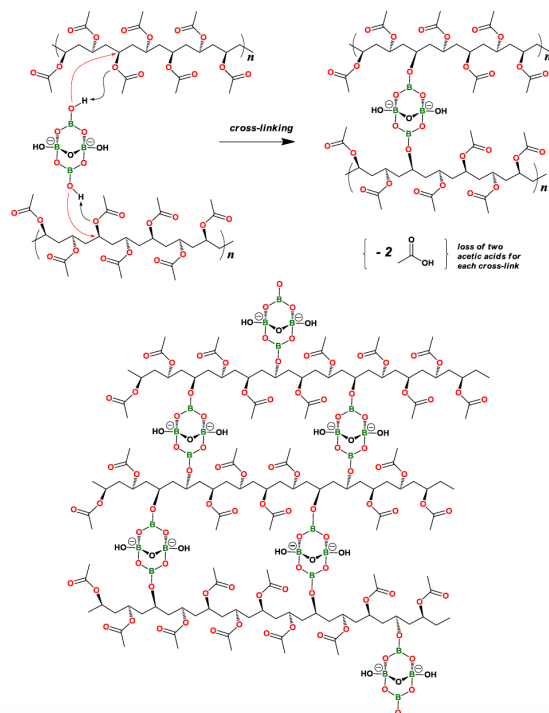
Once it has fully reacted, pull it out of the solution and keep kneading it – the water will be absorbed into the “silly putty”. Dry off your hands with a paper towel and it is ready to play with! Store it in a zip-lock plastic storage bag to keep it from drying out. If it gets into clothes or hair, it can be easily washed out with warm water. The “silly putty” is pretty much non-toxic (unless you eat way too much of it) and tasteless if eaten. The starting glue and “silly putty” are environmentally safe and biodegradable.

**Notes:** Two students should share each disposable bowl and take turns to prepare the “silly putty.”

- One 4 oz glue container should provide enough glue for 4 students. A typical class has 30 students in it, so you will need 7-8 glue containers for a class.
- Colored “silly putty” can be made by first coloring the glue by adding 5-10 drops of food coloring to the glue and shaking it up like crazy to mix the color into the glue. This takes some time for a full bottle of glue.
- A neat variant is to have one student make one color “silly putty”, while the second student makes a different color. They can then roll out each colored “silly putty” to make a rope and then braid them together, break in half, and then each student will have a bi-colored “silly putty”. As they play with it, the colors will very slowly blend together to make a new, third color.
- Another variant suitable for K-2 grades is to squirt two different color glues into the same bowl at the same time and mix them together. This will generate a new uniformly colored silly putty that is a mixture of the two original colors. This is a very nice hands-on demonstration of color mixing – perfect for kindergarten and first graders!!!

## Chemistry

Elmers Glue is made up of polyvinyl acetate, which reacts with water to some extent to replace some of the acetate groups with OH (alcohol) groups. The B-OH groups on the borax molecules react with the acetate groups on the glue molecules (relatively long polymer chains) to eliminate acetic acid and form new bonds between the borax and two glue molecules. The linking of two glue molecules via one borax molecule is called **polymer cross-linking** and it makes a bigger polymer molecule, which is now less liquid-like and more solid. The bottom figure shows that many of these borax crosslinks occur to “glom” together many polymer molecules turning them into a pliable solid “silly putty”. This really isn’t the silly putty you buy in the store, since it will dry out. Real silly putty is an organosiloxane polymer that doesn’t have any water in it so it doesn’t dry out.



**K-2 and Grade Activity:** You can have the students simulate this chemistry by having about 6 groups of 4 students hold hands and form glue chains. Have them walk around the front of the class. Then send out 6 individual students to act as borax molecules to grab onto two glue chains – one with each hand. Tell the glue chains that once they are grabbed onto by the borax students that they shouldn't try to break free. This should result in all the glue chains being linked together by the borax molecules (students). Now that all the students are linked together they represent the more solid "silly putty" that was formed in the experiment. This is a rather good physical analogy to the chemistry going on.

**Older Grade Upgrades (including High School):** This can be done several ways:

1. Have some of the students soak and mix the school glue longer in the borax water mixture. This will cause more cross-linking and make it less flexible and more prone to "breaking" and stretching less. On the other extreme you can have some do it for less time which will produce a material that is too goeey. Have the students compare the polymers they make and see if they can figure out what is going on chemistry-wise. 2)
2. Similarly, you can also dilute the borax-water solution by half and have two sets of students mix the glue for the same amount of time in the saturated borax-water and diluted borax-water and compare their putties.
3. You can use a gallon of school glue, a bigger mixing container, and a gallon of borax-water solution to make a gallon of silly putty. Few have seen this large amount and will find it fascinating even though they all have just made their own small batches. I typically have multiple pairs of students come up to dig their hands into the gallon of glue and mix it with the borax solution. You will need a large aluminum disposable pan to transfer the putty after mixing with the borax solution. If you have several students hold the mass and keep kneading it over the aluminum pan all the water will drip off or get absorbed. For fun you can have the class make a circle around the classroom and have them start to stretch the silly putty out to make a rope that extends around the entire classroom. They can then pull it back into the middle of the class to remake the big mass.