# Demonstration of a polymerization reaction[[1]](#footnote-1)

##

## Introduction

The term **polymer** means “many parts”; a larger molecule created by linking identical smaller molecules together. In this demonstration reaction you will create a polymer from polyvinyl acetate strands by adding a **cross-linker**, sodium tetraborate. A “cross-linker” is a chemical that reacts with two molecules and connects them at some point along their lengths, creating a larger molecule or polymer. As polymers form solutions become more **viscous** or resistant to flow. If the amount of cross-linking, or polymerization, is increased liquids will tend to act almost like solids.

Of course, polymerization reactions are chemical reactions. **Figure 1** shows a bit of the mechanism of the cross-liking reaction of polyvinyl acetate and sodium tetraborate.



**Figure 1:** *Overall crosslinking reaction of polyvinyl acetate and sodium tetraborate[[2]](#footnote-2)*

The two polyvinyl acetate strands are shown at the top and bottom of the first image and the tetraborate cross-linker is shown between them. Notice that the cross-linking reaction bonds the two strands of polyvinyl acetate by using the tetraborate as a bridge and releases two molecules of acetic acid. One acetic acid molecule is released from each strand of polyvinyl acetate and replaced by the tetraborate.

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**Figure 2:** *Some mechanistic detail for half of the cross-linking reaction*

**Figure 2** shows some of **mechanism** of the reaction. Note that boron has a very low electronegativity value (2.04) and is dipolar positive in the cross-linker. The polarity of the B-O bond makes the oxygen atom of the cross-linkers hydroxyl group dipolar negative and therefore reactive and looking for a positive group to react with. A pair of free electrons from that oxygen ‘attack’ the dipolar positive carbon of the polyvinyl acetate’s backbone to form a dative bond. To avoid five bonds, that carbon releases a pair of electrons in the bond to oxygen, freeing an acetic acid molecule. The oxygen of the acetic acid then picks up the hydrogen from the tetraborate in a final ‘polishing’ step.



**Figure 3:** *The polymer product, cross-linked strands of polyvinyl acetate*

Notice that the strands of polyvinyl acetate in the polymer product are cross-linked multiple times along their length. The more cross-linking, the higher the viscosity of the polymer.

**Materials:**

Chemicals: Equipment:

polyvinyl acetate graduated cylinders

saturated & dilute tetraborate solution ziplock baggies

food coloring pH paper

**Procedure:**

*Before beginning this demo, please consult the SDS for all chemicals. SDS can be found on CHE2060’s ‘Library of Labs’ page.*

1. Wear gloves and safety glasses while performing this experiment.
2. Pour about 20 mL of polyvinyl acetate from the beaker into a small ziplock bag. There is no need to measure volumes exactly.
3. Add some food coloring to make this more interesting. Feel free to mix colors, but don’t use more than 3 drops.
4. Seal the bag and mix the coloring into your polyvinyl acetate by squishing it around.
5. Pour about 10 mL of sodium tetraborate into your ziplock bag of colored polyvinyl acetate. There is no need to measure volumes exactly; rather try to maintain a 2:1 ratio for polyvinyl acetate : tetraborate.
6. Zip the bag shut and squish to mix the two solutions.
7. When the reaction begins to form a cohesive blob, you may take the blob out of the bag and continue to work it in your hands, kneading it to determine if there is any unreacted polyvinyl acetate left. (You don’t want liquid colored stuff squirting out the side of your blob of polymer, so mix it well in your gloved hands).
8. When the reaction has come to completion, pat the blob mostly dry with paper towels.
9. Congratulations! You have successfully performed the synthesis of a polymer!!!
10. Measure the pH of: 1) the polyvinyl acetate; 2) the tetraborate solution; and 3) the product. Does the change in pH from reactants to products make sense?

**Consider:**

* What should you add if your polymer is too liquid or sticky? Too solid?
* Could you do this experiment at home? Would it be safe? What common & easily purchased chemicals could you substitute for polyvinyl acetate and tetraborate?
1. Thanks to Page Spiess for introducing me to this lab exercise. [↑](#footnote-ref-1)
2. http://www.lsu.edu/science/chemistry/other/chem\_demo/Demo-3-Silly-Putty.pdf [↑](#footnote-ref-2)