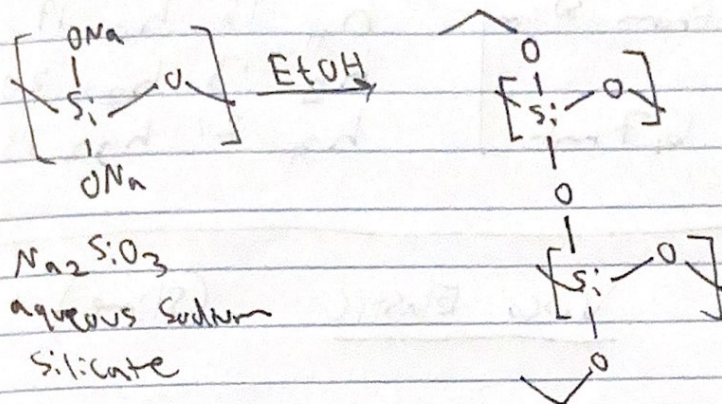


# Polymer

Purpose: Synthesize three types of polymers, Elastomers, Viscoelastic Polymers, and Network Polymers

## Elastomers (Bouncy Ball)



### Equipment

- Plastic graduated cylinder
- wooden stir stick
- 3 paper cups
- suction filter
- ruler

### Chemicals

- aq Sodium Silicate \*
- Ethanol \*

\* Organic waste

Hazards: Just wear gloves

### Procedure:

1) 10 mL  $\text{Na}_2\text{SiO}_3$  → Paper cup

$V_1$        $V_2$        $V_3$

2) add 5 mL Ethanol, ~~stir~~

$V_1$        $V_2$        $V_3$

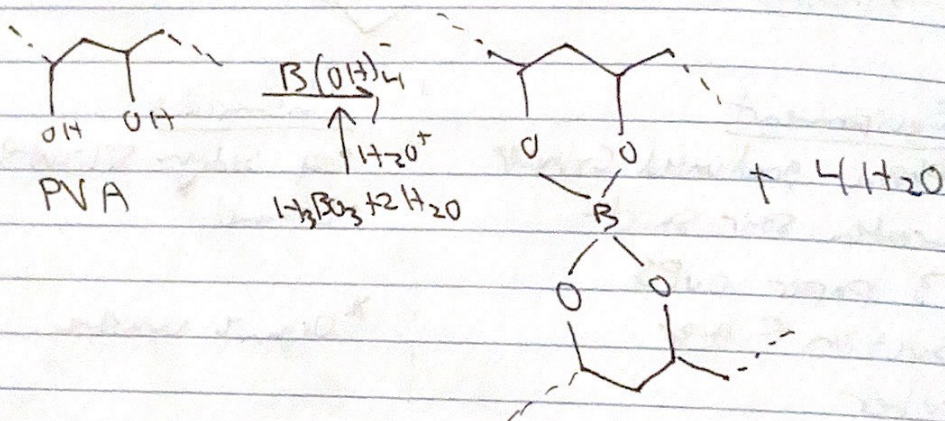
3) stir until solidifies  
- stir additional minute

4) suction filter



- Procedure
- 5) Press solid together to form ball  
- Wet it crumbles
  - 6) Bounce ball from 30 cm
  - 7) Repeat using 6, 7 ml Ethanol
- |          |    |          |    |          |    |
|----------|----|----------|----|----------|----|
| $h_{11}$ | 16 | $h_{12}$ | 19 | $h_{13}$ | 15 |
| $h_{21}$ | 13 | $h_{22}$ | 20 | $h_{23}$ | 21 |
| $h_{31}$ | 21 | $h_{32}$ | 15 | $h_{33}$ | 17 |

### Visco Elastic (Slime)



#### Equipment

- Grad. cylinder
- 2 Paper cups
- Stir rod
- 2 Ziplock bags
- Ruler / yard stick
- Plastic wrap
- Filter

#### Chemicals

- 4% PVA in H<sub>2</sub>O \*
- 4% Sodium Borate in H<sub>2</sub>O
- 8% Sodium Borate in H<sub>2</sub>O

\* organic waste  
† aqueous waste



## Procedure

1) Add 20 mL 4% PVA in paper cup

$$V_1 = 20 \text{ mL} \quad V_2 = 2 \text{ mL}$$

2) Add 3 mL 4% Borax

$$V_1 = 3 \text{ mL} \quad V_2 = 3 \text{ mL}$$

3) Quick stir  $\rightarrow$  transfer to Ziplock

- Solid forms quickly
- bubbles in slime after playing with it

4) Mix in Ziplock vigorously for 2 min

- 8% less viscous?

5) Set aside and repeat with 8% Borax

6) Measure viscosity with circles

$$r_1 = 0.55 \text{ cm} \quad t_1 = 47$$

$$r_2 = 0.55 \text{ cm} \quad t_2 = 25$$

7) Measure tensile strength:

a) place meter stick on table

b) roll ~ 20 g into 2 cm (D)

Sausage

c) Stretch slowly until snaps.

d) repeat Fast

slow	1	2	3
$\frac{t}{L}$	17	26	22
$\frac{L}{t}$	21	33	35
Fast	2	2	2
$\frac{L}{t}$	9	15	10

Fast

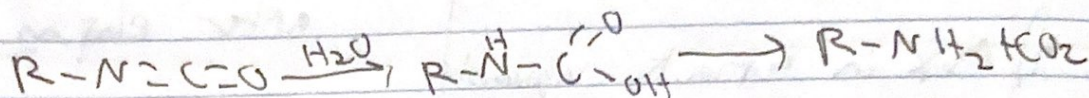
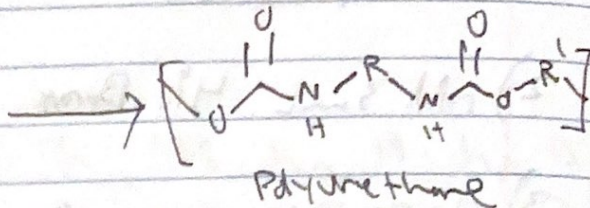
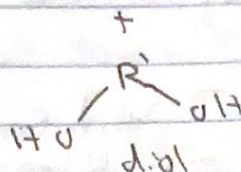
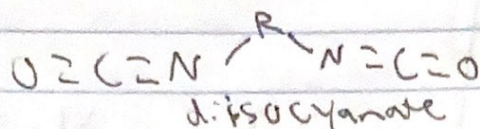
2	2	1
8	10	6

8%

slow	1	2	3
$\frac{t}{L}$	11	16	16
$\frac{L}{t}$	21	26	29



## Network Polymer (Foam)



### Equipment

- 4 Paper cups
- wooden stirrers
- Plastic Spoons
- weigh boats
- Cork bore
- Ruler
- Razor

### Chemicals

- Polyol \*
- Isocyanate \*
- \* organic waste

### Safety

- No glass wear
- wear gloves

### Procedure 9.2/0.8

- 1) add 9.0g - 9.9g Polyol  
with enough water to  
make 10g

poly 29.267 m water 0.86  
m m

- 2) Mix with wooden stick



### Procedure

3) ~~then~~ weigh 10g  
isocyanate in weigh  
boat (use plastic spoon)

$$m_1 = 10.0455 \text{ g}$$

4) Pour isocyanate into  
cup  
- Stir 30 sec

5) Let foam develop

Foam formed and  
grew - top fell off  
- brittle

~~6)~~ Repeat using different  $m_{\text{poly}}$   
+  $m_{\text{w}}$

✓ 7) Cup cut open with razor

8) Test density -

a) Use cork bore to extract  
~1cm X 3

$$m_{11} = 0.344 \quad m_{12} = 0.284 \quad m_{13} = 0.263$$
$$m_{21} \quad m_{22} \quad m_{23}$$

b) repeat for both foams

c) Plot Density vs. water

$$L_{11} 7 \quad L_{12} 7.2 \quad L_{13} 5.7$$
$$L_{21} \quad L_{22} \quad L_{23}$$

$$D_{11} 1.3 \quad D_{12} 1.3 \quad D_{13} 1.3$$
$$D_{21} \quad D_{22} \quad D_{23}$$

## Experiment 6 "Polymers"

### Silicone Elastomer

The goal of this experiment was to create three balls from sodium silicate and differing amounts of ethanol. These balls are considered silicone elastomers because they are elastic, meaning that the balls should have the ability to bounce and regain their shape after a certain stress is applied.

The backbone of a silicone polymer is made up of oxygen and silicon rather than carbon. Silicones are suitable for a variety of uses. In automobiles, silicone grease can be used to lubricate brake components, silicone rubber insulates the spark plug wires and even coats and seals airbags. Silicone rubber can also be used to make different types of cookware like rubber spatulas or ice cube trays. Silicones can be used as a dry-cleaning solvent, cosmetic implants, or even simple children's toys.

The bouncy ball made with 5mL ethanol bounced an average of 16.7cm. The 6mL ethanol ball bounced an average of 18.0cm and the 7mL ethanol ball bounced an average of 16.0cm. This data does not follow the expected trend that adding more ethanol would cause the ball to bounce higher. The 6mL ethanol ball bounced higher than the 5mL ethanol ball but the 7mL ethanol ball bounced lower than either of the other two. An increase in bounce height is expected with an increase in ethanol because when more ethanol is added, the polymer chains would be longer and packed more closely together so it would be more capable of cross linking and restoring its natural shape after an impact than a ball with less ethanol. It is possible that this trend was not followed because the balls may not have been allowed to dry entirely before testing them. The shape of each ball was very irregular and they often bounced out rather than straight up and down. This variability in shape could have affected the height that the ball bounced and definitely affected the reliability of the measuring method since the ball did not always bounce up close to the measuring instrument.

Polymers are long chains of monomers, meaning that the chemical composition of a polymer chain is a repeating sequence of specific elements or compounds. In the instance of the bouncy balls, sodium silicate was mixed with ethanol to form silicone polymer chains. When ethanol is added, the sodium leaves the sodium silicate and the remaining molecule bonds to other similar molecules forming a chain. When more ethanol is added, the longer the chain becomes because it would be able to react with even more sodium silicate and continue adding onto the chain. The ball with the most ethanol added would be the ball with the longest polymer chain and the ball with the least amount of ethanol should have the shortest chain.

The bouncing method could still be used to test the polymers elasticity but it would need to be improved by having a more controlled environment. When the test was performed, the ball was allowed to bounce around the desk so accurate readings were not easily obtained. A solution to this would be to bounce the ball inside a clear tube so the ball would be forced to bounce straight up and down the side of the measuring instrument. The elastomers tensile strength could be tested by placing the ball in a hydraulic press and record the amount of pressure needed for the polymer to crumble. While this method was not employed, it was observed that the ball with the most ethanol added seemed to be the hardest to press together and form a ball shape, but all three balls crumbled easily while trying to press into a ball.

## PVA Viscoelastomer

This experiment was intended to synthesize a viscoelastic polymer commonly known as slime. Since the slime is viscoelastic, the slime exhibits both viscous and elastic properties. The slime is a shear-thickening fluid so it displays more fluid-like properties when left alone but more solid like properties when under stress.

The borate ions are useful for cross-linking PVA because they can bond with the OH groups in the PVA. The boron is capable of creating four bonds with the OH groups in the PVA so when they link, the bonds form an “X” with the boron in the intersection. This effectively links two OH groups on one section of the chain to two OH groups on another section.

The data for the tensile strength test is displayed in the table below.

	Slow		Fast	
	4% Borax	8% Borax	4% Borax	8% Borax
Average stretching speed (cm/sec)	1.37	1.78	5.67	5.00
Average distance stretched before break (cm)	29.7	25.3	11.3	8.00

The slime in the slow trials stretched farther than the slime in the fast trials because when stretched slowly, the borate cross-links break and the polymer chain has time to untangle and slide around itself. When the slime is stretched quickly, the cross-links still break because they are relatively weak bonds but the chain is tangled and doesn't have enough time to straighten out before it gets caught on itself causing it to break.

The 4% borax stretched farther than the 8% borax in both the fast and slow trials. This can be explained due to the amount of cross-linking within the polymer. When more borate ions are supplied, then more cross-linking can occur causing the polymer to be more rigid and hold its shape better. This conclusion suggests that the 8% borax slime would have a slower flow rate for the viscosity test. However, the slime with 4% Borax had a flow rate of  $1.17E - 2 \frac{cm}{sec}$  and the slime with 8% had a flow rate of  $2.20E - 2 \frac{cm}{sec}$  suggesting that the higher the borate concentration, the less viscous the slime. This conclusion does not reflect the theory and is better explained by the imprecise nature of this testing method.

To test the viscosity of each sample, the slime was placed on a sheet of plastic in the middle of two concentric circles. When the slime reached the first circle it was timed until it reached the outer circle. There are many possible forms of error when using this method of testing viscosity. One reason the observed results may have differed from what was expected was the slime did not reach the entire circumference of the inner circle at once. This means that part of the slime reached the outer circle while other parts of the slime were still in between circles. This could cause discrepancies because if one slime is more lopsided than the other, it could potentially have a faster flow rate because only part of it would need to reach the outer edge rather than the entire slime reaching the edge uniformly. These discrepancies suggest that it may not be reasonable to compare the flow rate values of the two slimes because there was not an accurate and controllable method of determining when the slime reached each circle.

A better way of testing and comparing viscosity would be to place the slime in a tube, set the tube at an angle, and drop a ball down one side of the tube. The ball could slowly flow

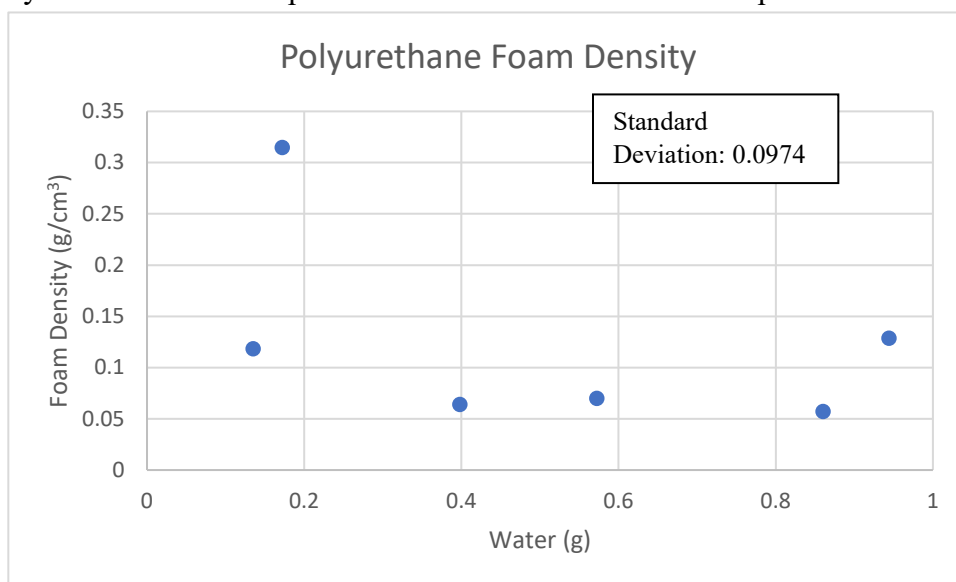
through the slime and the time it takes to get to the end could be recorded and compared with other samples. Another viscosity test is the “Zahn Cup” method where the fluid is placed in a cup with a hole in the bottom and the time it takes to fall out of the hole is recorded.

### Polyurethane Foam

Polyurethane foam has a variety of uses from insulation to kitchen sponges. The purpose of this experiment was to synthesize polyurethane foam from water, polyol, and isocyanate. The properties of the foam can be used to determine its best use.

After mixing each component, the foam quickly began to expand. One trial showed the foam expanding about 7cm above the rim of the cup. In other trials, the foam became too heavy and the top part fell over and stuck to the counter.

Changing the amount of water added to the solution would change the density of the polyurethane foam because the water reacts with the isocyanate providing carbamic acid which is unstable. The acid instantly breaks down to form amine end groups and carbon dioxide gas. This gas causes the solution to expand while it solidifies so it would be expected that the more water that is added, the more gas is produced, and the less dense the foam. This trend was partially observed in this experiment but there were several exceptions.



The second and last points on this plot show densities significantly higher than the previous points. These deviations can be related to deviations combining the separate components. The procedure instructed to mix the solution for about 30 seconds and then let it sit until the foam expands and hardens. Chemical reactions are dependant on the contact of individual molecules with other molecules which is why stirring and heating a solution often causes a reaction to speed up. In this case, if someone were to neglect the proper mixing of the reagents, then less water molecules would come into contact with the isocyanate molecules causing there to be less carbon dioxide gas which would lead to a higher than expected density.



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Commercially, polyurethane foam can have a density that ranges from  $0.048 \frac{g}{cm^3}$  to  $0.961 \frac{g}{cm^3}$ . The calculated densities observed in this experiment were on the low side of that range with  $0.057 \frac{g}{cm^3}$  as the least dense and  $0.315 \frac{g}{cm^3}$  as the most dense.