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Teacher Guide: Creating a Shape Memory Polymer from Silicone-1 Caulk, with Extension (Oil and Water Separation)

Pre-Lab Question

1. What does it mean for a substance to have shape memory?

Shape memory polymers have the capability to change into a different programmed shape, and then revert back to their original shape in response to a stimulus (for example, when heated).

Materials for Part 1

- Safety Glasses or Goggles
- Gloves
- 4 Plastic Cups (7 or 10 oz. size works best)
- Spatula
- Silicone-1 Caulk (in a caulk gun works best)
- Corn Starch
- MiraLAX (polyethylene glycol)
- Food Coloring
- 3-4 weigh papers

Helpful hints for the lab procedure from part 1:

- Silicone-1 Caulk gives off a very strong odor of acetic acid when setting up. It's recommended that you setup the caulk in the fume hood with the fan running, and have students measure out there. If possible, have the windows open to reduce the smell as well.

- When students are finished measuring the silicone-1, they should wrap a paper towel around the tip to capture any silicone that continues to release from the caulk gun as the pressure equalizes. When you are done for the day, wrap the tip with aluminum foil to easily seal it.

- Use metal spatulas if possible for stirring. The silicone pulls off easily from the metal once dry, using a paper towel. Popsicle or craft sticks also work, but should be thrown away after each batch.

- Gloves are recommended for when students are attempting to press their mixture onto the weigh paper and flatten it. If silicone accidentally gets on their hands, they should gently scrape it off with a paper towel before washing their hands. Some other suggestions are posted here: http://www.wikihow.com/Remove-Silicone-Caulk-from-Hands

- You may want to check out this video on "oogoo" – a mixture of corn starch and silicone --: https://www.youtube.com/watch?v=7fwytA5r2Mw

Part 2: Testing the Shape Memory Properties

Materials

- Safety Glasses or Goggles

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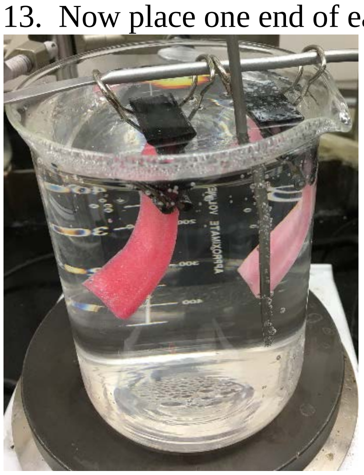
- Hot plate
- Scissors
- Thermometer
- 250 mL Beakers
- Stir rod (or spatula)
- 3 binder clips
- Masking or Beaker Label Tape

12. Expected results from the first trial:

Sample	Color of sample	Rank your samples in terms of best shape memory. (Did they retain the C-shape after the binder is removed?)	How did the texture change after being in the water?
Corn Starch: Silicone		*This sample displays **no shape memory** (stays flat the entire time)*	*Surface stays pretty much the same.*
1:2.5 MiraLAX: Silicone		*This should be the **2^{nd} best** at shape memory.*	*Surface becomes slick.*
3:1 MiraLAX: Silicone		*Typically this ratio has the **best** results, if all 3 samples prepared.*	*Surface becomes slick, and may start to develop a spongy texture.*

13. Now place one end of each sample back into the binder clip, and slide the binder clips back onto the stir rod. Suspend over the hot water beaker for 3 minutes.
Write your observations in the space below. What happens to each sample as they are heated back up above 60^{o} C?



The MiraLAX samples should revert to their flat shape when they are heated without being held in a C-shape from the binder clip.

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14. Remove from the hot water, and gently dry both samples with a paper towel.
15. Then repeat the shape memory test. Place each sample in a binder clip, so that they both form a C shape. Hang over the hot water for 2 minutes, then place immediately into the cold water for 2 minutes. Remove from the cold water, and remove the binder clip. Record your observations in the table below.

Trial 2

Sample	Color of sample	Rank your samples in terms of best shape memory. (Did they retain the C-shape after the binder is removed?)	Was there any change in the results from the 1st trial?
Corn Starch: Silicone		*Worst – no shape memory*	*No*
1:2.5 MiraLAX: Silicone		*2nd best – displays shape memory*	*No*
3:1 MiraLAX: Silicone		*Typically still the best, but will be much closer in results to the other ratio after the 2nd trial*	*Yes, performance usually worse than the 1st trial*

16. Clean up your lab area. Make sure to wash your hands before returning to your seat.

Post Lab Questions

1. The melting point of MiraLAX is ~55º C. By heating the sample above 60ºC, what did that cause to happen inside the mixture of MiraLAX: Silicone?

The MiraLAX melted, allowing the polymer chains of the silicone to move easily and deform into the C-shape created by the clamp.

Why didn't the corn starch: silicone sample work? The corn starch moves with the polymer.

2. Why was it necessary to cool the samples before removing the binder clip?

Cooling the sample brought the MiraLAX back into a solid state, locking them into place so that when the binder clip was removed, the sample held the C-shape.

If you removed the binder clip without cooling the polymer, both samples would just lie flat, because the new shape would not be "programmed" into the MiraLAX: Silicone sample.

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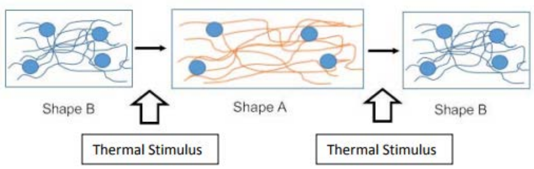
3. Draw pictures to represent what's happening at the molecular level in the MiraLAX: Silicone sample in the 3 phases of testing (at the start, after heated, after cooled down).



http://uakron.edu/cpspe/agpa-k12outreach/lesson-plans/pdf/Creating-Shape-Memory-Polymers.pdf

4. Why do you think the results changed from trial 1 to trial 2? (Hint: what happened to the texture of the samples?)

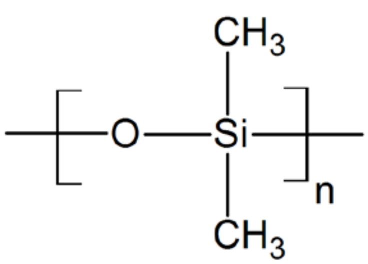
In the higher ratio sample, the sample performs better as there are more to help the polymer chains move and then lock in place when cooled. However, the higher ratio sample also loses more of the MiraLAX molecules to the water, as it is soluble. In the second trial, the amount of MiraLAX is similar in both samples, which makes their performance similar.

<u>Part 3: Mixture Separations</u>

<u>Pre-lab Questions</u>

1. In the web quest, you researched different methods of separating mixtures. Last class, your lab group placed the 3:1 MiraLAX: Silicone sample in a beaker full of water to soak. This will separate the mixture using what property?

2. The monomer that forms the base of silicone is



Calculate the difference in electronegativity for each bond in the monomer.

C-H __0.35_______ Is this bond ionic, polar, or nonpolar covalent? __nonpolar__________

C-Si __0.65_______ Is this bond ionic, polar, or nonpolar covalent? ___polar_________

Si-O __1.54______ Is this bond ionic, polar, or nonpolar covalent? ___polar_________

What intermolecular forces will most affect this compound?

Dipole-dipole and van der waals (London Dispersion)

3. MiraLAX is polyethylene glycol with a molecular weight of 3350. The monomer that forms the base of MiraLAX is

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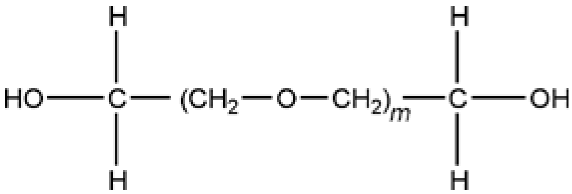

C-H __0.35_______ Is this bond ionic, polar, or nonpolar covalent? __nonpolar__________

C-C __0.00_______ Is this bond ionic, polar, or nonpolar covalent? __nonpolar__________

C-O __0.9_________ Is this bond ionic, polar, or nonpolar covalent? __polar__________

O-H __1.24_______ Is this bond ionic, polar, or nonpolar covalent? _ polar___________

What intermolecular forces will most affect this compound?

Hydrogen bonding, dipole-dipole, van der waals (London Dispersion)

4. Based on the intra- and intermolecular forces, which of the two substances (MiraLAX or silicone) would you predict would dissolve in water, which we know is polar-covalent? *Students should predict MiraLAX, due to the Hydrogen bonding. If not, discuss the -OH groups on the ends of the MiraLAX, and how that will affect the interactions.*

Procedure

1. Remove your 3:1 MiraLAX: Silicone sample from the beaker, and drain the water. Wash and dry the beaker.
2. Using paper towels, carefully squeeze the water out of your sample, until no more water comes out on the paper towel. **Record your observations about the sample below.** a) Does it still look like a solid plastic? b) What do you notice about the surface texture?

   Students should notice that the material now has pores, similar to a sponge.

3. Weigh your sample. Final mass of sample: _________________ g
4. Using your data from part 1 and 2 of the lab, complete the following table:

Part 1: Mass of Silicone in batch	Part 1: Mass of MiraLAX in batch	Part 1: Total Mass of batch	% Composition by mass of the MiraLAX in the original batch = $\frac{mass\ MiraLAX}{total\ mass}$	Part 2: Initial mass of the sample before soaking in water	Part 2: Calculate the mass of the MiraLAX in the sample you prepared: *multiply the % composition by the initial mass of sample*

5. Subtract the final mass of your sample from the initial mass of your sample from part 2 of the lab. Mass lost to the water = $M_I - M_F$ = ______________________ g

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6. Assuming that your sample only lost MiraLAX to the water, calculate the % of MiraLAX remaining in your sample using the following formula.

$$\%\ MiraLAX\ remaining\ in\ sample = \frac{Mass\ of\ MiraLAX\ in\ batch - Mass\ lost\ to\ the\ water}{Mass\ of\ MiraLAX\ in\ batch} * 100$$

% MiraLAX remaining in your sample = _____*typically around 85%*_______________ %

7. Refill the beaker with 250 mL of water. Add 1 drop of food coloring and stir.

8. Then using the pipette, transfer enough vegetable oil to completely cover the surface of the water.

9. Drop your sample into the mixture of oil and water. Using the tweezers, move the sample about the beaker to collect oil on the surface of the material.

10. Using the tweezers, remove the sample from the beaker onto a paper towel. Carefully remove the collected oil by squeezing with the paper towel.

11. Repeat steps 5 and 6 until you've removed as much of the oil from the water as you can.

12. Clean up your lab area, including washing the beaker and tweezers.

Post Lab Questions:

1. For this lab, the MiraLAX was removed from the MiraLAX: Silicone mixture by passively setting in water overnight. Based on your research on mixture separation, what are 1 or 2 ways that you might be able to increase the removal of the MiraLAX from the MiraLAX: Silicone mixture?

Heating up the water, as done in part 2, would help as the MiraLAX would melt and dissolve more easily. Other possibilities could be to increase the time soaked in the water, increase the amount of water that it is soaking in.

2. How efficient was your "sponge" at separating the vegetable oil from the water?

The sponge is not very efficient at picking up the vegetable oil, but the oil can be transferred using the sponge to paper towels.

3. Brainstorm with your lab partner to come up with 2 ways that you might be able to improve the oil and water separation technique that was used in this lab.

Answers will vary.

4. Based on your reading, which type of oil spill clean-up technique was simulated in this activity? Explain why, based on your observations in the lab.

Students may select skimmers (removing the oil from the surface similar to scooping it up, or sorbents (sponge or other porous material that soaks up the oil from the surface).