Slimy Spaghetti and Meatballs

Demonstration

Participants will learn about polymers and chemical bonding while creating a squishy and slimy version of spaghetti and meatballs.

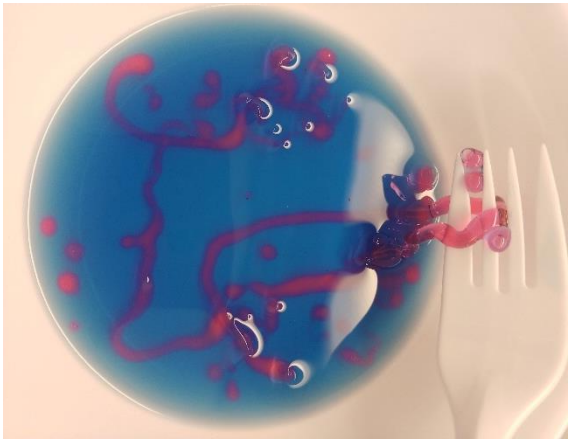

Figure 1. Illustration of demonstration final product

Number of Participants: 1-5

Audience: Elementary (ages 5-10) and up

Duration: 5-10 mins

Difficulty: Level 1

Materials Required:

- 3 g Sodium Alginate*
- 10 g Calcium Lactate*
    - Note: Calcium Chloride can also be used, as it is sometimes used in food chemistry processes, but this compound is very salty tasting.
- Cups or containers
- Stirring utensils
- Pipettes or any kind of squeeze bottle
- Water
- Food coloring (optional)

Note that these chemicals can easily be procured through online shopping, often as a kit. We don't recommend telling students to eat the produces to limit the transfer of germs.

Setup:

1. Dissolve 3g of sodium alginate in 197g water to make a 1.5 % by weight solution. It is recommended to use warm water to speed the mixing process along. You will likely need to stir or shake the mixture; be patient as this may be take a while. Add food coloring if desired.
2. Dissolve 10g of calcium lactate in 190g water to make a 5% by weight solution. Add food coloring if desired.
3. Once both mixtures are properly dissolved, pour the calcium lactate solution in a bowl or a similar container.
4. Fill a few pipettes with some of the sodium alginate solution. For several students, multiple bowl setups can be helpful.

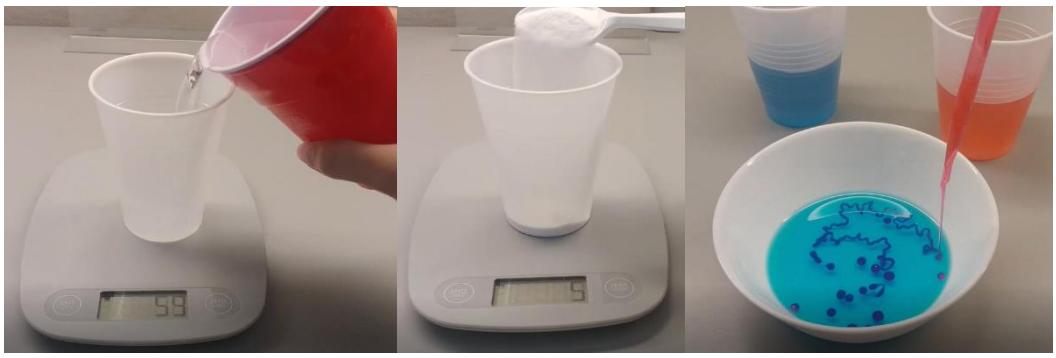

Figure 2. Illustration of demonstration setup

Presenter Brief:

Be familiar with what a chemical bond is, specifically be comfortable explaining broadly what a polymer is and how they are formed through being cross-linked. Know how to explain chemical reactions, molecule chains, and how polymers build up. Understand the basic chemical properties of sodium alginate and why a sodium alginate solution takes on a gel form when combined with a calcium lactate solution.

Vocabulary:

- Monomer – a type of molecule that can be reacted with other identical molecules to form a polymer.
- Polymer– a large molecule consisting of many repeating chains of monomers.
- Polymerization – the process of turning monomers into polymers via a chemical reaction.
- Cross-link – a bond that links one polymer chain to another
- Hydrophilic – when the molecules of a substance are attracted to water molecules.
- Sodium Alginate **–** extracted from seaweed and used as a thickening and stabilizing agent for various foods (e.g. ice cream, yogurt, salad dressing).
- Calcium Lactate – commonly used with sodium alginate in the spherification process.
- Spherification – a culinary process of combining sodium alginate with calcium lactate to transform a liquid to a gel.

Physics & Explanation:

Elementary (ages 5-10):

Start by introducing both solutions and invite the students to touch the Sodium Alginate solution. Get them to acknowledge that the Sodium Alginate and the calcium lactate solutions are liquids. **Take a survey of what the students think will happen when the sodium alginate filled pipette is emptied in the calcium lactate filled bowl.** Pass a few pipettes to a few students. Instruct them to try creating a spaghetti strand by squeezing a constant stream of material. To create the meatballs, instruct students to squeeze a few small droplets of the solution into the bowl. Help students pick up their creations from inside the bowl and let them examine the gel.

Leave some spaghetti and meatballs in the calcium lactate solution to sit for a few minutes and compare them to the ones the students took out earlier. Ask the students to squeeze some of the meatballs and compare how soft they are as opposed to the ones that were left in the calcium lactate solution for a longer amount of time. **Ask: What is the difference between the two?**

Figure 3. Popping Boba image from Fanaledrinks.com

Sodium alginate is a substance known as a polymer that is often extracted from seaweed. Polymers are long molecules that consist of chains of smaller molecules, often called monomers. These chains can chemically bond to each other in what is known as a cross-linked network to form a gel, as seen in figure 4.

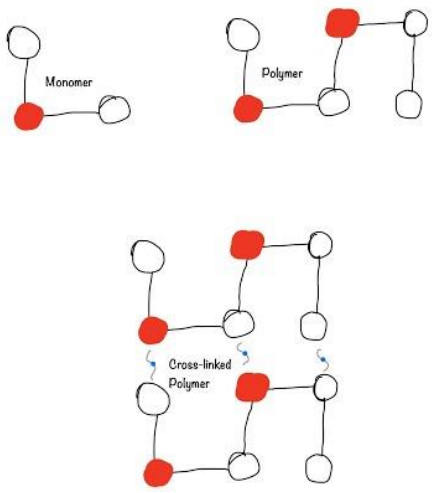

Figure 4. Diagram of Monomer, Polymer, and Cross-linked Polymer Structures. Data from "Risha's Science Notebook – 8th"

This demonstration uses sodium alginate as the polymer. When it is added to the calcium lactate solution, the dissolved calcium ions cause the chains in the sodium alginate to cross link and form a soft and squishy gel. Alginate is specific type of polymer that likes water, so as it meets the calcium solution, the alginate can store a large amount of water inside the network. The longer the sodium alginate stays in the calcium lactate, the firmer the gel will become. One of the most common uses of this process can be found in popping boba as seen in figure 3. Juice mixed with sodium alginate is dropped in a solution containing chloride to make this delicious and fun treat.

🔑 Alginate is a type of polymer that gels when it comes in contact with calcium ions by forming a cross-linked network.

Middle (ages 11-13) and general public:

Start by introducing both solutions and invite the students to touch the sodium alginate mix. **Take a survey of what the students think will happen when the sodium alginate filled pipette is emptied in the calcium lactate filled bowl.** Pass out a few pipettes to students and invite them to squeeze the material out inside the bowl. Instruct them to try creating a spaghetti strand by squeezing a constant stream of material. To create the meatballs, instruct students to squeeze droplets of the solution into the bowl. Help students pick up their creations from inside the bowl and let them examine the gel. Leave some spaghetti and meatballs in the calcium lactate solution to sit for a few minutes and compare them to the ones the students took out earlier. Ask the students to squeeze some of the meatballs and compare how soft they are as opposed to the ones that were left in the calcium lactate solution for a longer time. **Ask: What is the difference between the two? How can a solid be formed from two liquids? Challenge students to answer why the material left in the water longer feels more solid?**

Sodium alginate is a polymer. A polymer is a substance made of long repeating chains of molecules called monomers can have thousands, or millions of carbon molecules connected. Polymers have different properties depending on the types of molecules being bonded and the types of bonds. For instance, some polymers such as rubber can bend and stretch while glass and epoxy are hard and tough. In the case of gels, the polymers are connected in a way that forms what is known as a cross-link network. Physical cross-links, as seen in figure 4, are formed by weak interactions that allow chains to bond and create bridges between them.

When sodium alginate is dissolved in water, the negatively charged parts of the alginate become able to associate with other ions. Sodium is a singly charged positive ion and can only bind to one negative charge on alginate at a time. However, calcium, another positive ion, associates with two negative charges on alginate at the same time. This causes cross-links to form, creating a gel. Cross-linked polymers can be compared to Velcro pieces. If you only have pieces from the smooth side, the pieces do not stick together. When you add in the hook side, though, they can catch onto multiple smooth pieces, creating a polymer.

Sodium alginate is hydrophilic, which means its molecules are attracted to water molecules. This property allows the polymer to effectively store water inside the network, so the resulting gel becomes soft and squishy. Sodium alginate is widely used in food for its great thickening, stabilizing, and gel forming properties. Examples include popping boba as seen in figure 3, ice cream, salad dressings, pudding and fruit-filled snacks. Other common food items have polymer gels that are not necessarily like sodium alginate. Egg whites for example are composed of mainly protein and water. Protein is a natural polymer and it can be cross-linked when exposed to heat. When egg

whites are cooked, the heat disturbs the bonds that hold the protein molecules, causing them to break certain bonds and cross-link with each other to form a firmer gel.

- Alginate is a type of polymer that gels when it comes in contact with calcium ion by forming a cross-linked network. Sodium Alginate is commonly found in popular foods because of its gel forming properties. There are other types of natural polymer gels found in foods, like egg whites.

Additional Resources:

- Slimy Spaghetti and meatballs, The Society of Rheology, http://www.ecs.umass.edu/mie/faculty/rothstein/Outreach/Demo3.pdf
- More info on Polymers: https://www.livescience.com/60682-polymers.html
- Polymerization Process: https://www.rsc.org/education/teachers/Resources/inspirational/resources/3.1.9.pdf
- Spherification example: https://www.youtube.com/watch?v=6kp6qhxchdg

References:

1. Slimy Spaghetti and meatballs, The Society of Rheology, http://www.ecs.umass.edu/mie/faculty/rothstein/Outreach/Demo3.pdf
2. How popping boba is made: https://fanaledrinks.com/blogs/blog/18322291-how-is-popping-boba-made
3. Physics of Fluids 31, 072102 (2019); https://doi.org/10.1063/1.5100243
4. Zumdahl, Steven S., and Donald J. DeCoste. Introductory Chemistry. Cengage Learning, 2019.

Acknowledgements:

This demonstration is made in collaboration with the 2019 SOCK intern, Noura Ibrahim.